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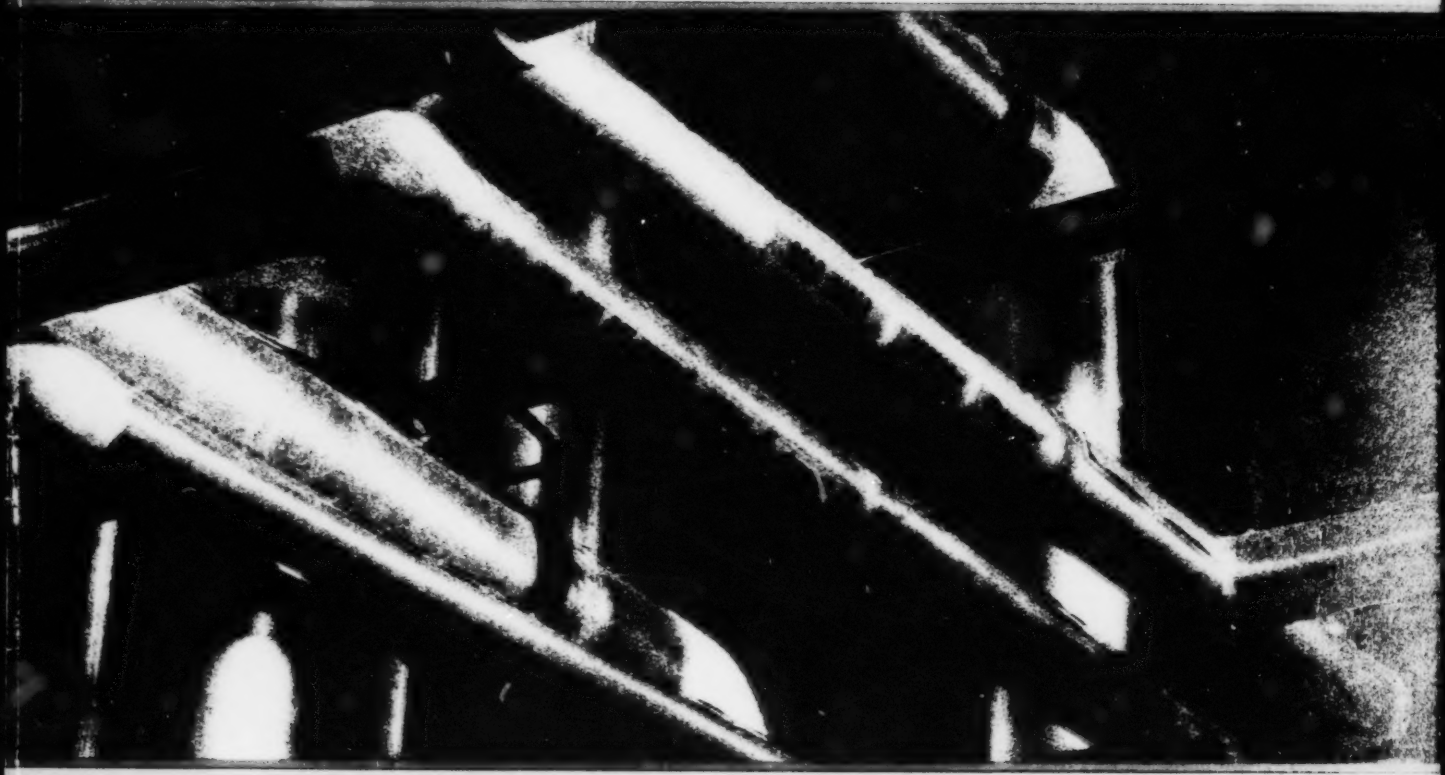
Energy Efficiency in Multi-Unit Residential Buildings: A Handbook for Owners and Operators



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Energy Efficiency in Multi-Unit Residential Buildings: A Handbook for Owners and Operators

Price: $6.00

Aussi disponible sous le titre de:
Gestion rationnelle de l'energie dans les immeubles d'habitation — Guide a l'usage des proprietaires et des administrateurs

Canada Mortgage and Housing Corporation

Société canadienne d'hypothèques et de logement

Honourable Romeo LeBlanc
Minister

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ISBN 0-660-11159-4
Cat. No. NH17-19/1982E

Printed in Canada

92-05902/

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PREFACE

This handbook is designed to promote the efficient use of energy and improve the standard of maintenance in multi-unit residential buildings. It is directed to owners, who make fundamental decisions about the way a building should be run, and to operators — including managers, superintendents, and maintenance staff — who are responsible for the day-to-day functioning of the building.

The handbook is divided into three chapters. The first briefly defines energy efficiency in the context of multi-unit residential building management, sets out standards to aim for, and describes the essential elements of an energy conservation program. This section will be of particular interest to owners.

Chapters 2 and 3 are intended primarily for use by operators. They present practical guidelines and instructions for the operation and maintenance of various types of equipment. Four appendices provide detailed examples and checklists that will help users apply the methods described.

This document was prepared for CMHC by Leslie Jones, P.Eng., of B.F.H. Shawinigan, Ottawa, under the guidance of John W. Sawers, Project Manager, Development Evaluation and Advisory Services, Canada Mortgage and Housing Corporation.

WHAT IS ENERGY-EFFICIENT MANAGEMENT?

Multi-unit buildings contain a variety of engineering systems that are designed to provide residents with a comfortable living environment. These systems include heating and ventilation, hot water, lighting, and cooling, and they serve both individual units and public spaces. They all consume energy in performing their respective functions. The amount of energy they use depends upon several factors: the size and design of the system, the quality of the equipment it contains, the manner in which it is operated, and the kind of maintenance it receives. All these factors depend, in turn, upon the owner's decisions about the management of the building. It is, then, the owner who controls the level of energy use in a particular residence.

Given present uncertainties about future energy supplies and the hard fact of rising costs, building owners, like everyone else, should be concerned about efficient energy use. Figure 1 shows the breakdown of expenses for a typical apartment building in Canada. It is evident that engineering systems (represented by "utilities" and "maintenance and repairs") account for a significant portion of total operating costs. To the extent that these costs can be reduced (without, it must be stressed, depriving tenants of a safe and comfortable living environment), the profitability of building ownership will be increased. The potential savings can be deduced from the energy cost data presented in Appendix 1.

How can an owner determine whether or not his building is energy efficient? To begin with, he can compare his own records of annual energy use with the regional targets (see Figure 2). These targets represent levels of energy consumption for a typical high-rise multi-unit dwelling that is well maintained and well operated.

The target figures do not take into account all the

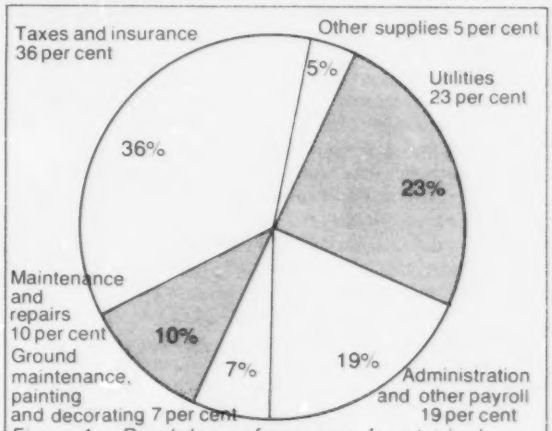


Figure 1. Breakdown of expenses for a typical apartment building.

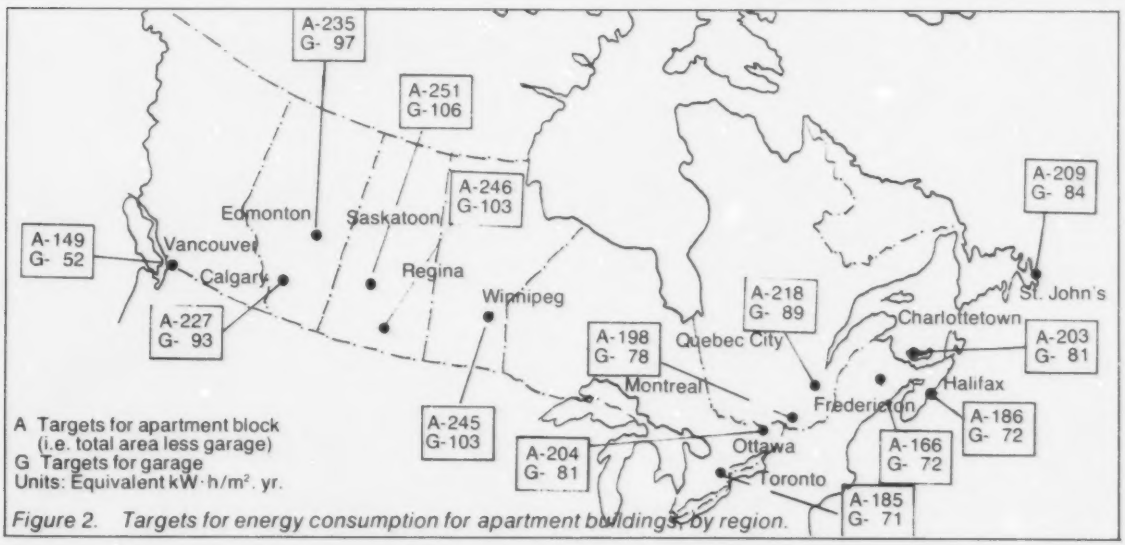


Figure 2. Targets for energy consumption for apartment buildings, by region.

differences that might exist between particular buildings, such as construction, age, number of units, and range of services — all of which may affect energy consumption. Nevertheless, they provide a standard against which any building can be compared. If an apartment residence is currently using substantially more energy than the target figure specified for that region, the potential obviously exists for improving the efficiency of the building. Even if a building is functioning at the recommended level without the benefit of an energy program, it is likely that consumption can be reduced.

In addition to rating a building against an energy target, an owner can compare the services currently being provided against the recommended minimum values for a comfortable living environment given in Tables 1, 2 and 3. Providing services in excess of these requirements will inevitably lead to increased energy costs. For example, it is recommended in Table 1 that the garage temperature be kept at 7 C, which some may feel is a little low; it must be remembered, however, that tenants will normally be dressed for the outdoors when they are in the garage and that they will generally spend only a small amount of time in walking to and from their vehicles.

Energy use in apartments varies enormously from building to building. A survey carried out by Ontario Hydro in 1976 showed a rate of consumption for a sample of 52 apartments in Ontario that ranged from a low of 13 kW·h/m² to a high of 96 kW·h/m². With such a spread of consumption it is extremely difficult to quote a single number that would represent a reasonable energy consumption. Many factors such as the insulating value of the walls, the amount and type of glazing, the infiltration rate, and the efficiency of the heating, ventilating and air-conditioning systems all contribute towards a fuel consumption unique for a particular building.

Once an owner has assessed his building and determined that it can and should be improved, the next step is to set up a plan for achieving this goal.

Table 1 Recommended Space Temperatures[a]

Space	Winter (C)	Summer (C) (If air conditioned)
Dwelling units	20	26
Dwelling units (senior citizens)	22	26
Assembly spaces[b]	20	26
Entrance halls, corridors	18	28
Entrance vestibules	10	*
Stairways[c]	16	*
Laundry rooms and washrooms[c]	18	*
Storage rooms	10	*
Garbage rooms	7	*
Equipment rooms	10	*
Garages	7	*
Unoccupied units	10	*
Exercise rooms	16	*
Swimming pools	26	*

[a] Check that the levels specified comply with local codes
[b] When space is not in use, lower heating to 10 C in winter; turn off air-conditioning in summer
[c] At night, lower heating to 10 C in winter; turn off air-conditioning
* Air-conditioning not required

ELEMENTS OF AN ENERGY-EFFICIENCY PROGRAM

A building owner can reduce the use of energy in a building in four basic ways:

1. by ensuring that mechanical and electrical equipment is operated properly;
2. by ensuring that appropriate maintenance procedures are carried out on a regular schedule;
3. by adapting or replacing inefficient equipment; and
4. by upgrading the building envelope by additional insulation, recaulking and weather stripping of windows and doors.

These methods can be applied without necessarily incurring large costs. In fact, by following the procedures recommended in this handbook, the building owner will generate savings that will more than offset the investment required to achieve them.

The four measures set out above form the core of an energy-efficiency program. If it is to be effective, however, the program must contain other elements as well, specifically:

- clearly defined scope and objectives
- an implementation plan

Table 2 Recommended Lighting Levels for Public Spaces[a]

Space	Level (lux) and where measured	
Assembly Spaces[b]	150	1.2 m above floor
Entrance halls, corridors[c, d]	150	1.2 m above floor
Stairways[d]	100	on stair tread
Storage rooms, garbage rooms[b]	50	on floor
Laundry rooms and washrooms[b]	200	on 1.2 m above floor
Equipment rooms[b]	50	on floor
Garages	50	on floor
Swimming pools[b]	300	at water level
Exercise rooms[b]	150	1.2 m above floor

[a] Check that the levels specified comply with local codes
[b] Turn off lighting when spaces not in use
[c] Lighting may be reduced by 50 per cent at night-time
[d] In senior citizens' residences, lighting levels should be increased by 50 to 100 per cent over recommended levels

CAUTION should be exercised when considering lighting reductions in corridors and staircases.

Table 3 Recommended Ventilation Rates[a]

Space	Ventilation rate
Apartment units:	
General living areas[b]	1 air change per hour
Kitchen[c]	24 L/s
Bathroom[c]	8 air changes per hour
Garage[d]	236 L/s per parking space
Public spaces:	
Corridors, entrance halls[e]	0.0000182 L/s m^2
Assembly rooms	0.00154 L/s m^2
Exercise rooms	0.000365 L/s m^2
Public washrooms	24 L/s per fixture
Swimming pools	0.000274 L/s m^2
Laundry rooms[f]	0.00022 L/s m^2

[a] Check that the rates specified comply with local codes
[b] Mechanical ventilation only required if openable windows not provided
[c] Ventilation only required when room is in use
[d] Alternatively, ventilation can be controlled by CO monitor to limit CO concentration to not more than 50 ppm
[e] Ventilation is normally provided to control air movement from public space to tenant space
[f] Additional volume may be required to prevent excessive temperature in space

- a monitoring system and
- periodic evaluation.

Each of these elements is described more fully below.

Scope and Objectives

The scope and objectives of the program are determined by the resources available to the owner, the nature of the building's present engineering systems, and the energy targets the owner is aiming at.

The critical resources are capital and personnel. The owner must decide how much money he wants to spend on upgrading equipment and improving operations and maintenance, bearing in mind that savings may be used to fund further changes. He must also decide whether his present staff are capable of carrying out the full range of operational and maintenance procedures, and if they are not, how he can ensure that the program is implemented.

The condition of existing equipment will have a bearing on the capital investment required; it may restrict the level of improvement that can be attained in the short term although there should be some immediate benefit. In buildings where the engineering systems are basically sound and complete, substantial gains should be attainable at a reasonable cost.

The kind of equipment installed in a building, and the number of buildings to be serviced, can also affect the scope of the program. For example, buildings that

include air-conditioning systems, swimming pools, laundry facilities, and garages will call for a wider range of operating and maintenance procedures than will buildings that do not.

The objectives of an energy-conservation program, generally stated, are to save energy and reduce expenses associated with the operation and maintenance of equipment. In addition, there are more specific objectives that each owner must identify for his own building or buildings. These goals may be defined in terms of dollar savings or energy consumption levels, or both, and they may include secondary objectives, such as improved tenant or staff satisfaction. A realistic schedule should be established for the achievement of program objectives.

It is important that the objectives be decided at the very start of the planning process, though they may be modified later. They will shape the development of other program elements, and, at a later stage, serve as a measure of the program's effectiveness.

Implementation Plan

The implementation plan sets out a detailed strategy for achieving the objectives of the program. It should specify the kind of work that is required to lower energy consumption, prolong equipment life and identify the personnel needed to carry out the work.

The kind of work required — such as cleaning, repair, modification or replacement of equipment — will depend upon the characteristics of the engineering systems that are in place, the condition and operation of particular items of equipment, and the general condition of the building. It follows, then, that as a preliminary step the owner must become familiar with the building's systems and equipment.

Information about systems and equipment is usually contained in an operation and maintenance manual. All buildings should have one, though some do not. In the event that there is no manual, the owner should have one prepared. It should include:

- a complete set of "as-built" drawings, which have been updated to show any changes made since construction
- operating and maintenance instructions for all mechanical and electrical equipment, plumbing fixtures, and architectural hardware, such instructions to be developed from manufacturers' brochures and manuals, supplemented by information supplied by the building designer and/or contractor
- a list of recommended spare parts and suppliers from whom they can be obtained
- names, addresses, and telephone numbers of the designer(s) and major contractor(s) who worked on the building, local authorities, and utility companies providing services
- commissioning data, such as air and water flows, and regulating valve positions.

Referring to the manual, the owner should carry out a survey of existing systems and equipment, recording their condition, age, performance, and other pertinent information. The survey will help him to organize a maintenance program, and make a reasoned judgement about the ability of his present staff to upgrade and maintain the equipment to program standards.

Staffing is the most critical aspect of the implementation plan. Without competent personnel, no program — however well planned in other respects — will succeed. A key person in the plan is the building operator, the individual responsible for the day-to-day running of the building. The building operator may or may not be a skilled technician or tradesperson. In any case, it is unlikely that they will possess the extensive knowledge required to service all types of mechanical and electrical equipment. What is more important is that they should be familiar with the building's engineering systems, and committed to achieving the objectives of the energy-efficiency program.

It is obvious that the persons who actually work with the equipment should be qualified and competent to do so. An owner who is responsible for several apartment buildings may find it economical to hire one or more full-time technicians to service all his buildings as required, or to supervise less qualified staff. For owners whose resources are more limited, day-to-day operations and maintenance may be entrusted to an employee on the premises, and outside contractors be called in when additional work must be carried out. In either case, the owner should recognize the skills and limitations of his staff, and augment their abilities by providing outside assistance when it is needed. Table 4 lists some of the agencies and service groups that may be able to help with implementation of the program.

Monitoring System

An energy-efficiency program should be monitored, first, to ensure that it is proceeding according to plan, and, second, to provide a record of what is achieved during the implementation process. The principal tool of a monitoring system is the maintenance of written records.

The people who service equipment should supply complete and accurate records of the work that has been done, the date it was carried out, other work that is required, and the present condition of the equipment. These records will provide assurance to the owner or building operator that specified procedures are being

Table 4 Some Sources of Advice and Technical Assistance in Implementing an Energy-efficiency Program

Agency or service group	Services provided	Cost
Utility companies	Will explain basis for service charges.	No charge
	May suggest alternative tariffs and ways of limiting demand.	
	May carry out a simple energy audit.	
	May recommend energy conservation practices.	
Government agencies (e.g., National Research Council, Division of Building Research; Canada Mortgage and Housing Corporation)	Provide technical literature.	Nominal fee or no charge
	Offer general guidance on energy conservation practices.	
	Answer general technical questions or refer to appropriate source of information. They cannot advise on products and cannot be expected to solve specific problems.	
Manufacturers and suppliers of equipment and materials	Usually provide advice on products they make or stock.	No charge
	Provide information on operation and maintenance of equipment or use of materials, however they cannot be relied upon to give a completely unbiased opinion.	
Maintenance and service contractors	Provide services ranging from maintenance and repair of individual items of equipment to complete operating and maintenance packages for entire building.	Fee for service
Consulting engineers	Conduct energy audits of existing buildings.	Fee for service
	Develop energy systems management programs.	
	Conduct feasibility studies.	
	Redesign engineering systems.	

followed, and they will help identify problems that may interfere with the achievement of the program's objectives.

For the purpose of assessing the results of the program, records of energy use and costs are most valuable. (Suggested formats are provided in Appendix 2; these may be copied and used for keeping records.) Records must be complete if they are to serve their intended purpose. The persons who have to fill out these forms should understand why the information is being collected, and be encouraged to draw attention to any anomalies that appear in the records between recording dates.

Records of energy use, if kept on a monthly basis, define a pattern from which deviations can be readily identified. Not all records are of equal usefulness. Simple annual totals of, say, oil, gas, or electricity consumption are too gross to serve as a measure of energy efficiency; and daily or weekly logging of performance for individual items of equipment is often more time consuming than informative. Particular logging methods suit some situations better than others. The owner should consider the methods available and choose the ones that best serve his needs.

Several methods of obtaining and interpreting data on energy consumption are described below. Examples of all calculations are given in Appendix 1.

Annual Records

In their simplest form, annual records note gross annual consumption data for a particular building. They document total litres of oil, cubic metres of gas, and kilowatt-hours of electricity used over a twelve-month period. Year-to-year comparisons can be made from these data, but comparisons will be improved if figures are normalized to eliminate year-to-year weather differences. The normalizing factor suggested for use is average annual degree days, as set out in the National

Building Code of Canada (Supplement).[1] Values for major locations across the country are shown in Table 5.

As well as adjusting figures to accommodate changes in weather conditions, gross consumption data may be broken down into the separate amounts used for different purposes. For example, if a building is heated by electricity, the amount of energy used for lighting and power must be deducted from the total before heating consumption can be determined. In general, it is reasonable to assume that 80 per cent of the total can be allocated to heating and 20 per cent to other purposes. In making year-to-year comparisons, the degree-day correction should be applied to the 80 per cent figure. Similarly, if the fuel used for heating is also used for heating domestic water, the degree-day adjustment should be applied to 80 per cent of the total amount of consumption.

Another way of separating energy consumption for heating from that used for domestic hot water is to record the rate of consumption during the summer months, when space heating is not required. From these data, annual consumption for domestic hot water can be estimated, and the amount deducted from the total to arrive at the figure for heating consumption. (Note that in the case of an electrically heated building consumption for lighting and power must also be included in the deductible amount.) The calculations described here are illustrated in Appendix 1.

To permit comparison of the performance of a building with others of a similar type, consumption figures can be normalized by area, either the total area for the building or the area for specified spaces (rental units, laundry facilities, garage, and so on). It is essential that definition of floor area be applied consistently to all buildings being compared.

Monthly Records

Monthly records provide a continuous check on the performance of a building. Consumption data for heating may be normalized, as described earlier, using

Table 5 Degree Days for Selected Locations in Canada

Locations	Degree days below 18°C
British Columbia	
Fort Nelson	7 063
Vancouver	3 007
Victoria	3 076
Alberta	
Banff	5 719
Calgary	5 345
Edmonton	5 589
Lethbridge	4 718
Saskatchewan	
Moose Jaw	5 400
Regina	5 920
Saskatoon	6 077
Manitoba	
Churchill	9 213
The Pas	6 852
Winnipeg	5 889
Ontario	
Kapuskasing	6 366
Ottawa	4 673
Thunder Bay	5 746
Toronto	4 082
Québec	
Montréal	4 471
Québec	5 080
Sept Iles	6 135
Val d'Or	6 146
New Brunswick	
Fredericton	4 699
Saint John	4 771
Nova Scotia	
Halifax	4 123
Sydney	4 459
P.E.I.	
Charlottetown	4 623
Summerside	4 600
Newfoundland	
Goose Bay	6 522
St. John's	4 804
Yukon Territory	
Whitehorse	6 879
N.W.T.	
Alert	12 930
Yellowknife	8 593

[1] The concept of degree days is commonly used to estimate the heating requirements of residential buildings. One heating degree day results for every degree that the average daily outside temperature is below a predetermined base temperature. For present purposes, a base of 18°C should be used.

the ratio of degree days in the month to the average monthly degree days.[2]

One problem in keeping monthly records is that data are not always comparable for a given period; for example, it is seldom possible to record precisely the amount of oil consumed in a month, unless an installation is equipped with meters for this purpose. Similarly, meters for different utilities — gas and electricity — are not always read on the same day, making it difficult to arrive at an accurate figure for monthly energy consumption.

One way of dealing with the problem is to choose dates in each month between which energy consumption data will be tabulated (preferably, the dates on which one of the utility meters is usually read). Consumption of other fuels is apportioned to this period according to the number of days covered, and the average daily consumption is calculated from fuel bills received during this period. (See Appendix 1 for an example of this calculation.)

Sliding Annual Energy Consumption

A useful energy accounting technique that accommodates both long-term and short-term effects otherwise provided separately by annual and monthly records is the sliding annual energy consumption method. A graph is constructed using monthly fuel consumption data, updated each month. Each new point on the graph represents the previous twelve months' consumption. (See Appendix 1.)

Equivalent Kilowatt-hours

Energy consumption data are not always comparable because consumption may be measured in different units: fuel oil in litres, gas in cubic metres, and electricity in kilowatt-hours. To facilitate comparison, it is common practice to convert data for oil and gas into equivalent kilowatt-hours. Examples of such conversion are shown in Table 6.

Financial Records

Records of expenditures on energy quickly identify the effectiveness of an energy-conservation program. Again, though, it is inaccurate to compare data for different periods without adjusting them to take into account changing conditions — notably, cost increases and weather. A method of adjusting cost data to arrive at an accurate "cost avoidance" figure is shown in Appendix 1.[3]

Evaluation

The fourth essential element of an energy-efficient program is evaluation. When the program has been in effect for a reasonable period (say, twelve to eighteen months), its results should be thoroughly assessed, and further evaluations should be undertaken at regular intervals thereafter.

The energy-consumption and cost data collected during the monitoring process, and subsequently adjusted for comparison and interpretation, will show how effective the program has been. If the results fall short of the original objectives, the reasons should be determined. Perhaps the objectives were not realistic; perhaps implementation of the program was impeded by lack of competent staff or difficulty in scheduling work; perhaps greater capital investment is needed to upgrade existing equipment. Whatever the cause of the shortfall, the program should not be stopped; it should be redesigned so that previous problems will not recur. Closer monitoring may be advisable, particularly during the early months following renewal of the program.

If the program has been effective in its initial implementation phase, it may still benefit from modification and refinement. It should not be left to "run itself"; continuous monitoring and periodic evaluation are necessary to ensure that it works as it should.

A successful program can be modified to respond to changing circumstances such as increased energy costs, tax incentives and grants for energy conservation measures. Discuss your program with others in the same position as you, and listen to and encourage comments from all concerned with the program.

Table 6 Equivalent kW·h (eq. kW·h) of Some Common Fuels

Fuel	kW·h
1 litre #2 oil	10.3
1 litre #4 oil	11.0
1 litre #5 oil	11.3
1 litre #6 oil	11.8
1 cubic metre of gas	10.9

[2] Average monthly degree days are printed each year in *Annual Meteorological Summaries*, published by Environment Canada. Month-by-month summaries are available from Environment Canada or from local weather offices.

[3] Cost avoidance is the difference between actual fuel bills and the cost that would have been incurred if no energy-saving practices had been introduced.

CHAPTER 2 OPERATION OF MECHANICAL AND ELECTRICAL EQUIPMENT

HOW OPERATING PRACTICES AFFECT ENERGY USE

Mechanical and electrical systems and the equipment they contain must be operated properly if they are to perform their intended functions. Incorrect operating practices can lead to deterioration, malfunction, and eventual breakdown. They can also result in levels of energy consumption that are much higher than they need be.

These observations may seem obvious, yet inefficient functioning of mechanical and electrical systems can often be traced to poor operating practices. The operator may be ignorant of how the system works, he may disregard or misunderstand operating instructions, or such instructions may be missing or incomplete. In such circumstances, it should not be surprising that equipment does not perform efficiently.

When the goal is to save energy, it is first necessary to make sure that equipment is being operated properly. Those who control the engineering systems of a building must understand the workings of those systems, and be competent to operate all components. If this prerequisite is met, it should be possible to keep energy consumption at reasonable levels.

Complete operating instructions should be contained in the building's operation and maintenance manual. (See Implementation Plan in Chapter 1.) The operator should refer to this manual before handling any item of equipment with which he is not familiar, and whenever he is confronted with an unusual problem. If the manual is not complete, it is the responsibility of the building's owner to arrange for missing information to be supplied.

As important as correct operating practices are, they will not necessarily, by themselves, produce energy savings. All they will do, in most cases, is reduce the likelihood of excessive consumption. To achieve notable reductions in energy use, the operator must combine correct operating practices with planned conservation techniques: running equipment for shorter periods, taking advantage of external elements that might supplement a building's systems, scheduling the use of equipment to match the need for its output, and adapting the design of a system to increase its efficiency and performance.

The basic features of all the major engineering systems in a multi-unit building must be understood if energy-efficient operation is to result. Only then can detailed suggestions for energy-saving operating be put into practice. Energy-saving practices are discussed fully below and are summarized in the form of a checklist in Appendix 3.

HEATING AND VENTILATION SYSTEMS

Heating and ventilation systems account for the largest share, by far, of total energy use in multi-unit buildings. Figure 3 illustrates typical proportions of energy consumption for these systems (in combination with air conditioning) compared with the level of energy use of domestic hot-water and electrical systems. An operator needs to know how all these systems work to ensure that they function efficiently.

Five basic concepts influence the design of heating and ventilation systems: heat transmission, solar heat gains, internal heat gains, circulation of air, and infiltration/exfiltration. These factors determine the heating requirement of any space in a multi-unit building. Each is explained briefly below.

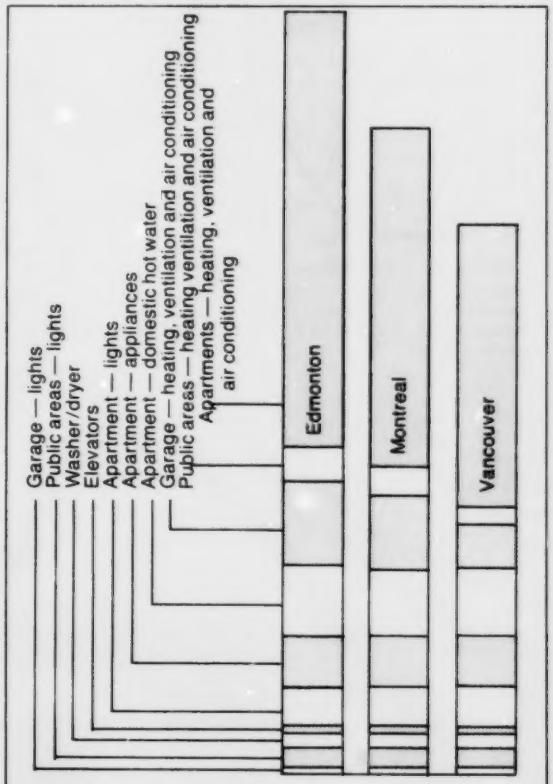
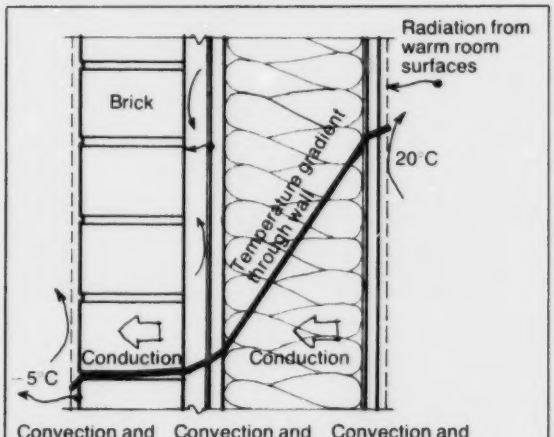


Figure 3. Typical breakdown of energy use in apartment buildings.

Heat Transmission

Heat may be gained or lost through the structural enclosure of a space (that is, through the walls, roof, or floor) whenever there is a difference in temperature between the enclosed space and an external adjacent space. This phenomenon is known as heat transmission or heat transfer. It occurs through three interacting natural processes: convection, conduction, and radiation. Figure 4 illustrates heat transmission through walls of typical construction in an apartment building.



	RSI
Air film	0.02
100 mm brick	0.14
Air gap	0.17
Building paper	—
12.7 mm fibreboard	0.17
140 mm R20 insulation	3.50
6 mil air/vapour barrier	—
12.7 mm gypsum board	0.08
Air film	0.02
	4.10

Figure 4. Heat transmission or transfer.

Solar Heat Gains

Solar heat comes from the sun; most solar heat enters through windows (some is actually absorbed by the outside wall and transmitted to the space). The sun is radiant energy and as such cannot warm air directly, but must first warm a surface, such as a wall or floor, which in turn will transfer heat by convection to the room air. Some of this heat will be radiated to other surfaces. This process of first warming a surface, then transferring the heat to the air takes time. If the floor is bare concrete or stone it will take a long time for the sun to warm the space as it must first warm the concrete, which will tend to "soak up" the sunshine. If, on the other hand, the floor is of lumber covered with a good insulator such as a carpet, the sun will quickly warm the room.

Solar gains are independent of air temperature, and will vary with time, window placement and amount of cloud cover.

Internal Heat Gains

Heat is generated within a building through the presence of people and the use of energy-consuming equipment, such as electric lights and household appliances. These internal sources contribute towards the heating requirements to maintain comfort conditions in the space.

Circulation of Air

Air must be circulated or replaced in any inhabited space so that the quality of the air is maintained at an acceptable level. Where artificial cooling devices are not installed, circulation is useful in maintaining the desired air temperature.

Circulation can be achieved by "mechanical" means through the use of fans or by "natural" means through the opening and closing of windows. These methods of creating air flow are complemented by the leakage of air through the building fabric — the process of infiltration and exfiltration.

Infiltration and Exfiltration

Air flows through the fabric or structure of a building when there is a difference between the internal and external air pressure. The direction of flow is from high pressure to low. Differences in internal and external conditions affect the rate and direction of air flow. Some examples will illustrate the process.

During cold weather, warm air inside the building rises (as warm air always does) to upper levels, where it leaks out into the colder outside air. The air that is lost through leakage at the top (exfiltration) is replaced through leakage into the building at the bottom (infiltration) (see Figure 5). The air that enters from the outside is cold (the same temperature as the outside temperature). As it passes through the building's heating system, it is warmed, rises, and leaks out at upper levels. This "building stack effect" is illustrated in Figure 6.

The rate of infiltration depends upon the height of the building, the difference between the inside and outside temperatures, and the airtightness of both the exterior walls and the interior partitions (walls, floors, and ceilings). If a completely airtight barrier were placed halfway up the building, two independent stack effects would occur (see Figure 7). This "local" stack effect can also occur across a single floor; for example, when a patio door is opened on a cold calm day, cold air can be felt entering at the floor level and warm air escaping at the top.

Wind also affects air flow through a building. As it passes over a building, it creates a positive pressure on the windward side and a negative pressure (a partial vacuum) on the leeward side. This pressure difference induces a flow of air through the building (see Figure 8). The rate of flow depends upon the geometry of the building, the strength and direction of the wind and the airtightness of the exterior walls and interior partitions.

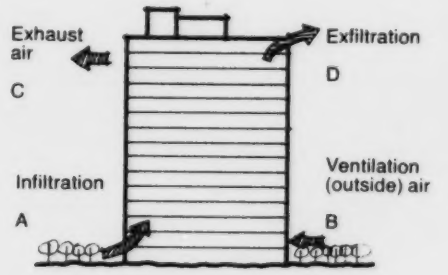


Figure 5. Air balance in an apartment building. Volume of air A & B = Volume of air C & D

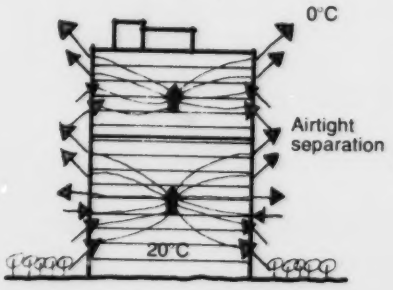


Figure 7. Local stack effect.

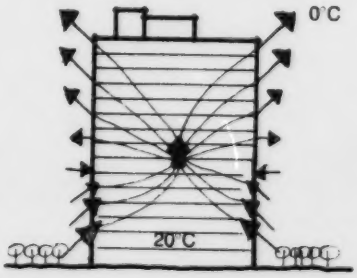


Figure 6. Building stack effect.

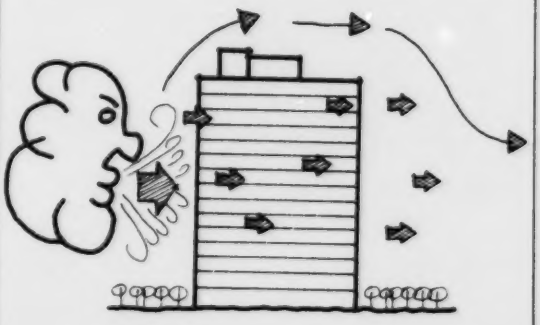


Figure 8. Wind-induced infiltration.

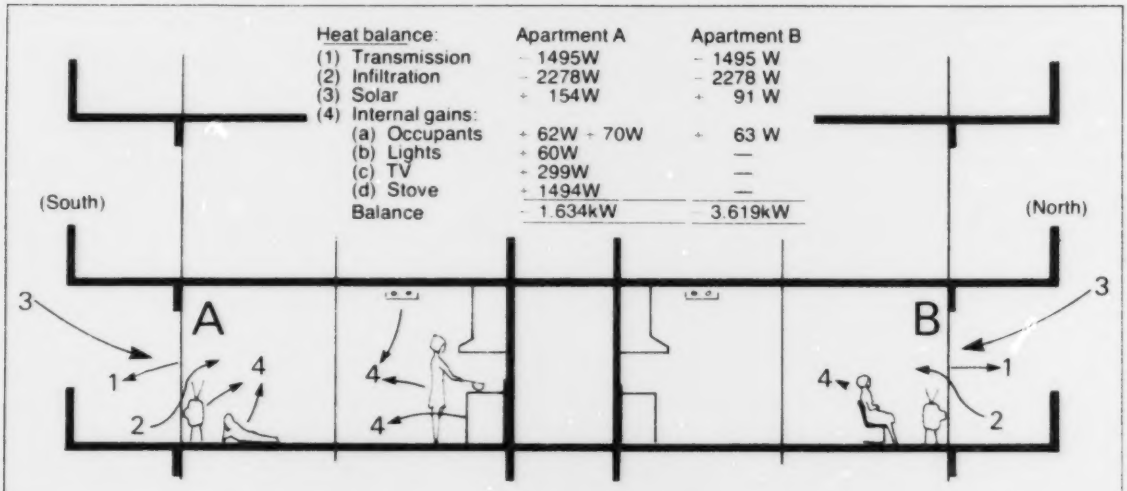


Figure 9. Hypothetical heat gains and losses in two apartment units.

Heating Requirements

The interaction of the factors described above in determining the heating requirements of a building is illustrated in Figure 9. It should be noted that the heating requirements can vary considerably according to the exposure of a space to solar radiation and the use of the space. In the drawing, apartment A gains more heat than apartment B through solar radiation, higher occupant activity, and greater use of household appliances and lighting. The amount of supplementary heat that must be supplied to maintain a comfortable inside temperature is therefore less for apartment A than for apartment B. It follows, then, that the heating system of the building should incorporate control devices to adjust the supply of heat to the requirement of a particular space at a particular time. The use of such devices is discussed later in this chapter.

HOT-WATER HEATING SYSTEMS (HYDRONIC SYSTEMS)

The essential components of a hot water (or hydronic) heating system are the water boiler, burner, circulation system, space-heating devices, and temperature controls.[1] Some systems may include a shell and tube heat exchanger or a heat pump.

Water Boilers

A boiler is a device for converting the energy in fuel (coal, oil, gas) to heat and transferring the heat to water. It may be made of cast iron or steel.

A cast-iron boiler is usually the shape of an inverted horseshoe; sections are connected by nipples to form waterway passages (see Figure 10). Steel boilers are

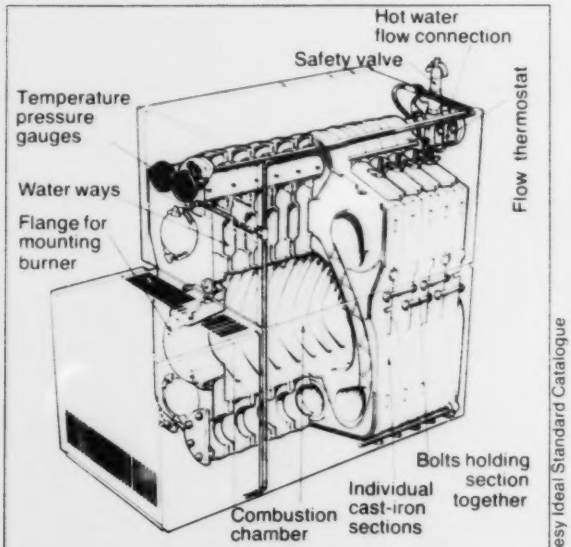


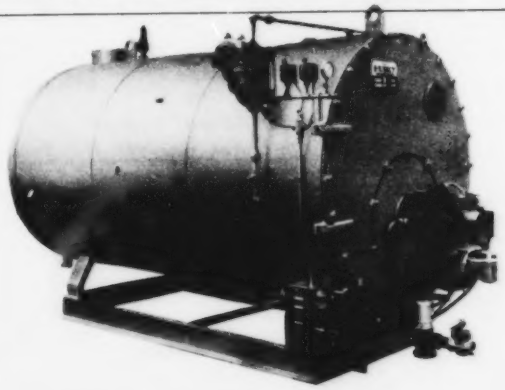
Figure 10. Cut-away view of cast-iron boiler.

Courtesy Ideal Standard Catalogue

[1] The heating systems described here are common types. In any building, however, differences in design and equipment may exist. Operators should study the system they have, so that they understand exactly how it works.

normally welded into a single rectangular or cylindrical unit. The heat-exchange surface is usually an assembly of vertical, slanted, or horizontal tubes. The tubes may contain either water or flue gas. The latter type, known as a fire-tube boiler, is shown in Figure 11.

All boilers are equipped with controls that regulate the rate of fuel input and heat output as the demand for heating changes. Most large boilers can be fitted with any type of burner (coal, oil, or gas). Small boilers may be built specifically for a single fuel, notably gas.



This particular model is a three-pass modified Scotch-marine type. Water surrounds the fire tubes at the back of the boiler and the hot combustion gases pass up and down the boiler three times in a cycle.

Figure 11. A large fire-tube boiler.

Courtesy Raypak Catalogue

Burners

A typical gas-fired boiler is shown in Figure 12. This model is fitted with an atmospheric burner, which draws combustion air from the atmosphere. This type of burner is simple, quiet in operation, and inexpensive; however, its controls are usually limited to two operating modes: on/off or high/low/off.

Power burners use a fan to supply and control the combustion air. They may be designed for natural draft or forced draft; the forced-draft type is shown in Figure 13. The principal advantages of power burners are their superior control of combustion and their wide range of operating modes. Forced-draft burners also eliminate the need for a chimney to draw smoke from the boiler.

When oil is used to heat water in a boiler, the fuel must be converted to a gas, vapour, or fine spray before it is introduced into the combustion chamber. This function is performed by an atomizing burner. The most common type, shown in Figure 14, is of either forced-draft or natural (induced)-draft design. The former offers advantages similar to those of the forced-draft gas burner.

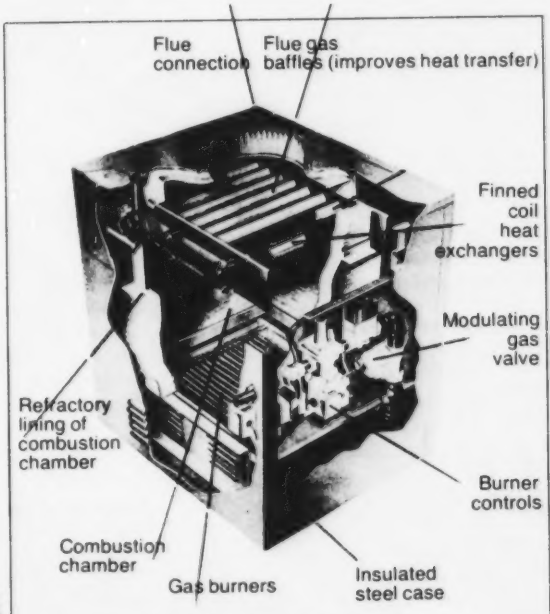


Figure 12. Cut-away view of a gas boiler equipped with atmospheric burner.

Courtesy Raypak Catalogue

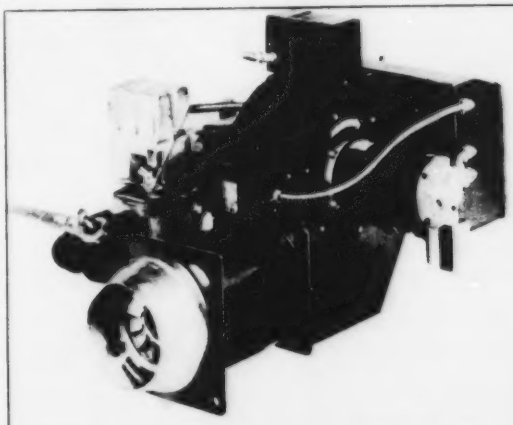
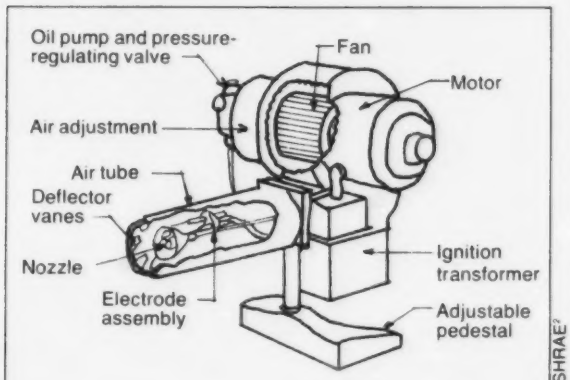


Figure 13. Forced-draft power gas burner.

Courtesy Power Flame Division Incorporated Bulletin

Simple oil burners operate in an on/off mode, with a single firing rate. There is also a more sophisticated burner available, with a high/low firing rate that improves the boiler's efficiency during periods of light demand. This modulating burner, potentially the most efficient, has a variable burning rate and maintains high efficiency over a wide range of loads.



Courtesy ASHRAE[2]

Figure 14. High-pressure atomizing oil burner.

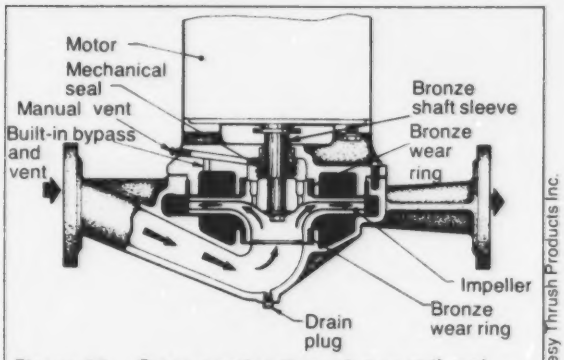
Circulation Systems

Once the water has been heated to the desired temperature it must be circulated through the building to all areas that require heat. Circulation is usually effected by a centrifugal pump and a network of pipes. Water enters the eye or centre of the pump impeller, which rotates to create the pressure required to force the water through the piping system. Examples of common pump assemblies used in apartment buildings are shown in Figures 15 and 16.

The pipework is, of course, a crucial part of the circulation system. Some common arrangements are illustrated in Figure 17.

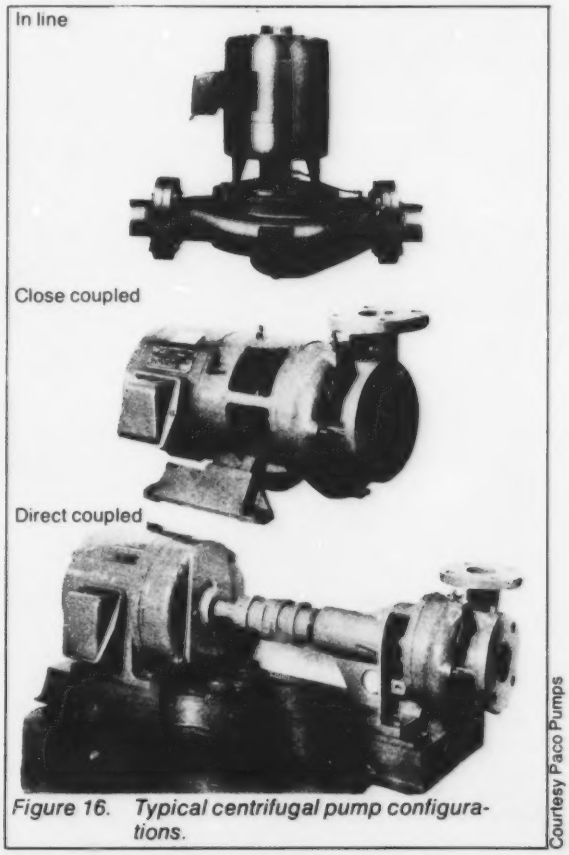
The simplest and least expensive piping arrangement is the single-pipe series system shown in Figure 17. It is, however, the least satisfactory of the four varieties shown, as the water becomes progressively cooler as it flows through the loop. It also has the disadvantage of having no mechanisms for selective heating of the building. The water must flow through the whole system, regardless of the heating requirements of the various spaces or living units it serves.

An improvement on the series system is the single-pipe diverting system shown in Figure 17. Here, through a combination of radiator controls and bypass



Courtesy Thrush Products Inc.

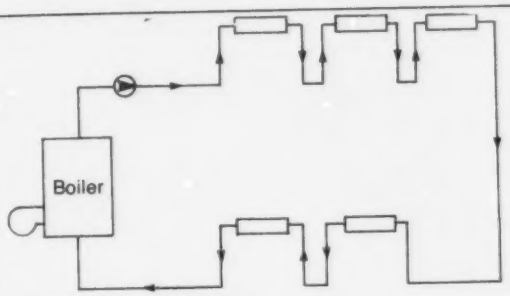
Figure 15. Cross-section through a centrifugal pump.



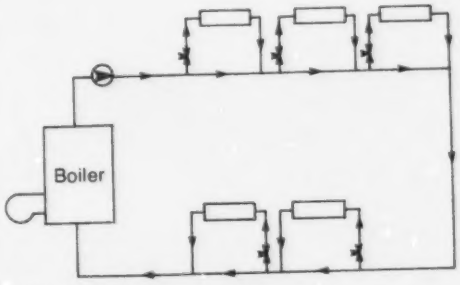
Courtesy Paco Pumps

Figure 16. Typical centrifugal pump configurations.

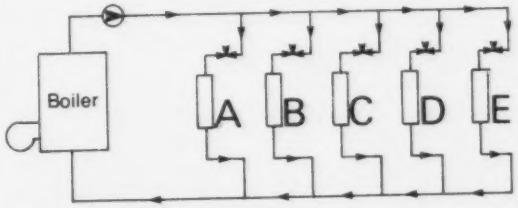
[2] American Society of Heating, Refrigeration and Air Conditioning Engineers.



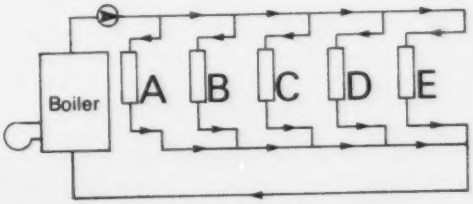
A. Single-pipe series system



B. Single-pipe diverting system



C. Two-pipe direct-return system



D. Two-pipe reverse-return system

Figure 17. Basic water-piping arrangements.

piping, selective heating can be achieved. But with this system, as with the series arrangement, water temperature still varies as it flows through the piping network.

The two-pipe systems shown in Figure 17 are a further improvement over the single-pipe diverting system in that they maintain a more consistent water temperature throughout the system. The pattern of circulation may be direct return or reverse return. In the direct-return system, the water flow is uneven, because the circuits nearer the boiler offer less resistance than those farther away. To correct this, balancing valves must be installed and adjusted so that resistance to water flow in each of the circuits is balanced. The reverse-return arrangement is potentially self-balancing, because the pipes in each circuit are all of equal length.

Space-heating Devices

Several devices are available for space heating within a building served by a hydronic system. Three common devices are radiators, convectors, and low-temperature panels.

Early radiators were of the cast-iron column type (Figure 18). These still exist in some older buildings. More common, however, are pressed-steel radiators (Figure 19). Between 30 per cent and 50 per cent of their heat output occurs through radiation; the rest is by convection. Heat output can be regulated by varying the rate of water flow through the system or the temperature of the water supplied to the unit.

Convectors basically consist of an extended surface coil (a series of waterways or tubes whose effective surface is increased by the use of metal fins) over

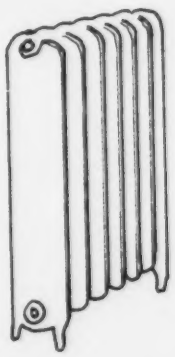
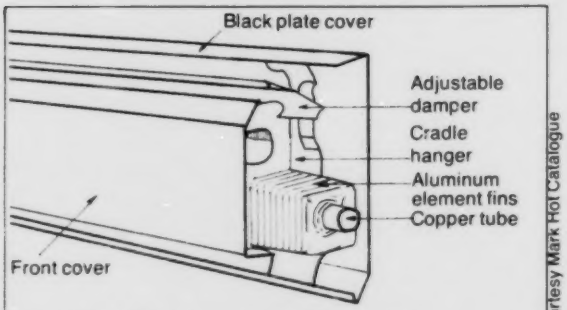


Figure 18. Cast-iron radiator.

Courtesy Chartered Institute of Building Services Engineers (CIBS)

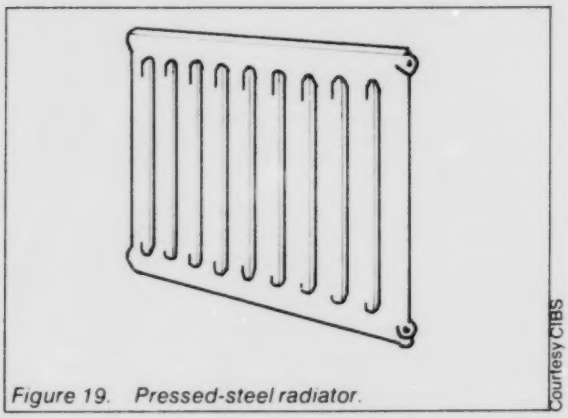
which air is induced to flow either by natural means or by the use of a fan (see Figures 20 and 21). Again, the output of heat can be regulated by varying the water flow or temperature; the air flow over the coils can be controlled by the use of dampers or a fan. Unit heaters (Figure 22) are a special type of fan converter often used for heating large open spaces such as garages.

Low-temperature panels consist of pipes embedded in the ceiling or floor (see Figure 23). They are an unobtrusive form of space heating, but they present control problems because they are slow to respond to varying conditions.



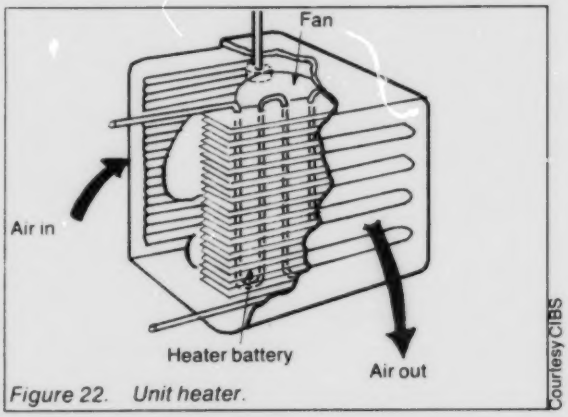
Courtesy Mark Hot Catalogue

Figure 21. Baseboard convector heater.



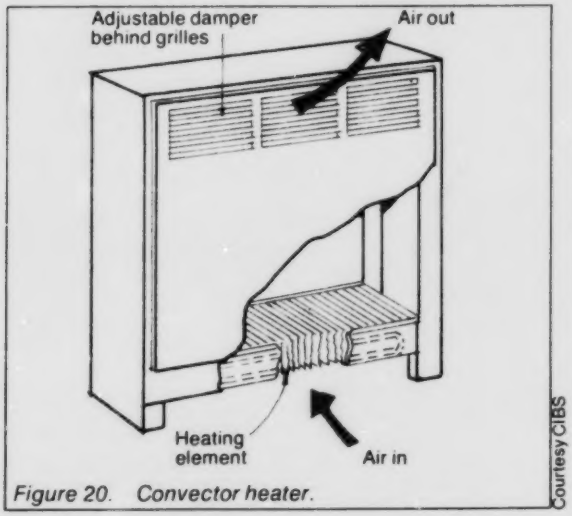
Courtesy CIBS

Figure 19. Pressed-steel radiator.



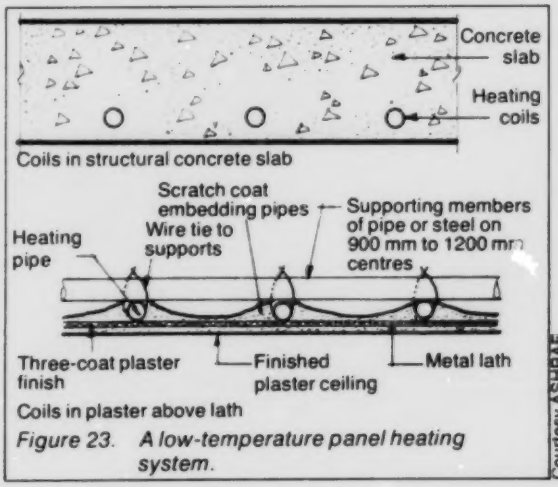
Courtesy CIBS

Figure 22. Unit heater.



Courtesy CIBS

Figure 20. Convector heater.


Concrete slab
Heating coils
Coils in structural concrete slab
Scratch coat embedding pipes
Supporting members of pipe or steel on 900 mm to 1200 mm centres
Heating pipe
Wire tie to supports
Three-coat plaster finish
Finished plaster ceiling
Metal lath
Coils in plaster above lath

Courtesy ASHRAE

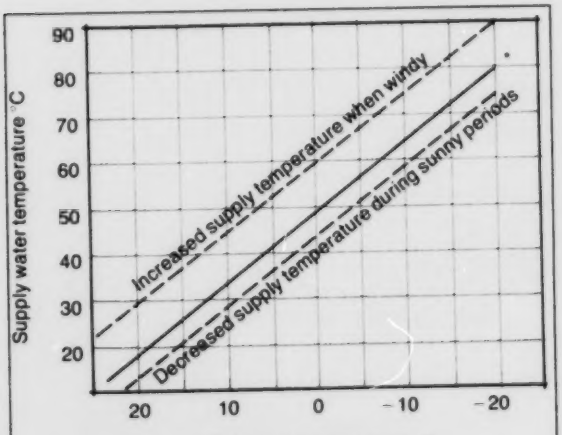
Figure 23. A low-temperature panel heating system.

Temperature Controls

The simplest method of control in a hydronic heating system is the boiler-mounted thermostat. This regulates the operation of the burner to keep the water in the system at a nominally constant temperature. Heat is supplied to the building at a constant rate, unless the building operator manually resets the boiler thermostat as the weather changes or tenants alter the heat output in their apartments by adjusting hand valves on radiators or dampers on convectors. Overheating is almost inevitable in systems controlled in this manner. Other controls are therefore recommended to replace or supplement a simple boiler thermostat.

The alternative is to set the water temperature according to the heating requirement of a "representative" space in the building. The problem is to decide which space is representative. If, for example, a south-facing apartment is chosen, all north-facing units will probably be underheated. Similarly, if a north-facing apartment is the model, south-facing units will be overheated.

A common and effective device is the outside reset control. This mechanism varies the system's water temperature in accordance with changes in the outside air temperature. The amount by which the water temperature changes for each degree of change in outside air temperature is called the reset ratio.



* The solid line shows the variation of supply water temperature with outside air temperature. The dotted lines show how this basic schedule can be adjusted to compensate for windy and sunny conditions.

Figure 24. Outside reset control of supply water temperature.

Controllers are available with a choice of fixed or variable reset ratio. The correct selection and adjustment of these controllers can have a significant impact on energy use.

Because other factors such as solar heat gain, wind, and internal heat gain influence the heating requirement of a given space at a given time, the outside reset control is not ideal. It can, however, be improved by the addition of wind and/or solar compensators, which modify the reset schedule to accommodate changing conditions, but this usually requires the heating system to be divided into zones. Figure 24 illustrates the effect of these compensators.

The ideal control scheme would provide controls in every room or every apartment in the building. Although individual controls may be misused by tenants, they are the most accurate means of adjusting the operation of the system to actual heating requirements. Controls may take the form of wall-mounted thermostats, or be attached to space-heating devices as shown in Figure 25.

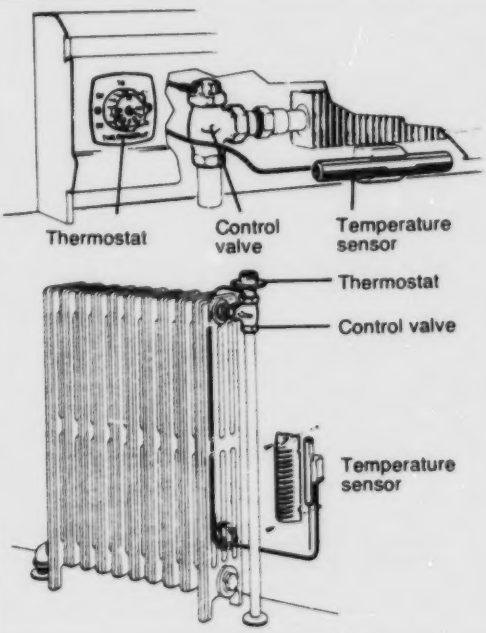


Figure 25. Direct-acting thermostatic valves for control of baseboard heaters and radiators.

Courtesy Danfoss Products Catalogue

Shell and Tube Heat Exchangers

Shell and tube heat exchangers (shown in Figure 26) are used to transfer heat from one system fluid to another system fluid: for example, steam to hot water, high-temperature hot water to low-temperature hot water, or refrigerant to water. They are normally found in large systems, such as a district heating scheme. Individual boilers are replaced by a shell and tube heat exchanger, and heat is transferred from the primary district heating fluid to the hydronic system of each building.

Heat Pumps

Another popular system used in multi-unit buildings is the closed-loop reversible heat pump system, or incremental system as it is sometimes called. The system configuration is shown in Figure 27. Individual units can provide heating or cooling, depending upon the position of the refrigerant reversing valve in the heat pump.

In the heating mode, the units extract heat from the water loop; in the cooling mode, they inject heat into it. The water-loop temperature is normally maintained between 16°C and 35°C. If the temperature falls too low, heat is added to the loop by a boiler or other heat source. If the temperature rises too high, heat is rejected at a central cooling tower. The advantage of such a system is that it can redistribute heat from one part of a building to another.

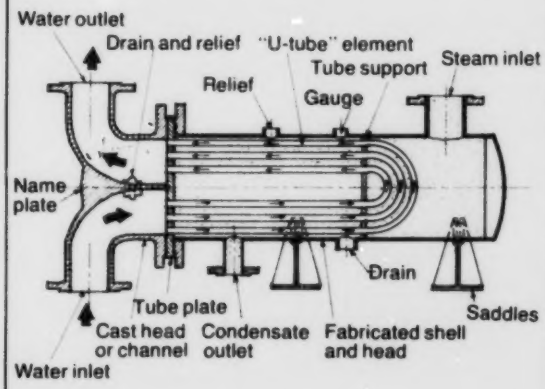
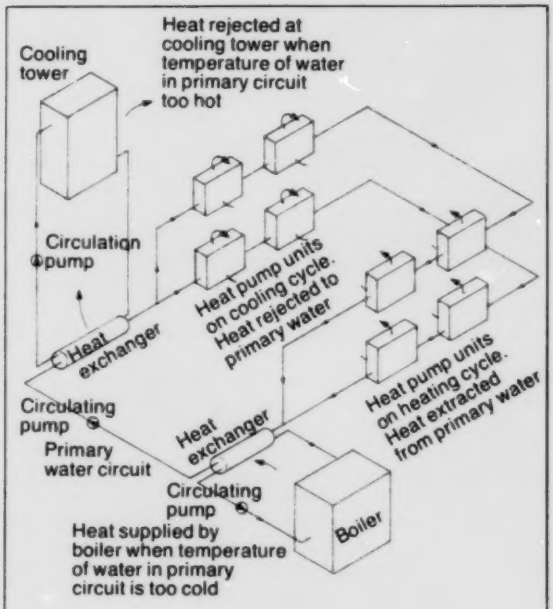
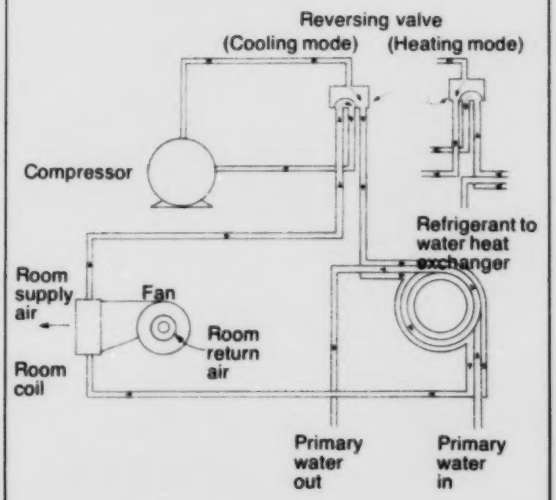


Figure 26. Typical shell and tube heat exchanger.


Cooling tower
Heat rejected at cooling tower when temperature of water in primary circuit too hot
Circulation pump
Heat exchanger
Heat pump units on cooling cycle. Heat rejected to primary water
Circulating pump
Primary water circuit
Heat exchanger
Heat pump units on heating cycle. Heat extracted from primary water
Circulating pump
Boiler
Heat supplied by boiler when temperature of water in primary circuit is too cold



In cooling mode, room coil acts as an evaporator. In heating mode, room coil acts as a condenser, rejecting heat to the space.

Figure 27. Incremental heat pump system.

STEAM HEATING SYSTEMS

In steam heating systems, water is heated in a boiler to create steam. The steam is then delivered to space heaters (radiators, convectors, or heating coils), where it condenses as it releases its heat. The condensed steam (condensate) is then either returned to the boiler or wasted to the sewer. These systems can distribute large quantities of heat through relatively small networks of piping; consequently, they are often preferred for large heating installations and district heating schemes.

Many older apartment buildings have steam heating systems. New buildings may also use steam supplied by a district heating system, but in such instances, heat is usually transferred from steam to water by means of a shell and tube heat exchanger.

Modern steam heating systems can vary the steam pressure and temperature over a wide range to provide good control of space heating. Some use outside reset controls similar to those described earlier for hydronic heating systems under Temperature Controls.

Steam systems vary in the piping arrangement they use, their operating temperature and pressure, and the means by which condensate is returned to the boiler. In one-pipe systems, a single main suffices to supply steam to a heating unit and return condensate from it. In two-pipe systems, each heating unit is provided with two pipeline connections, and steam and condensate flow in separate mains.

In gravity systems, condensate is returned to the boiler under the action of gravity alone; steam flow results from pressure created by the boiler. Mechanical return systems use traps and pumps to return condensate to the boiler.

Steam traps perform two important functions: they hold the steam in the pipework and heating device until it has given up its latent heat (that is, has condensed); and they vent condensate and non-condensable elements (such as air and carbon dioxide). When they are correctly installed and operated, they can conserve steam, improve distribution of heat, and improve control-valve action.

ELECTRIC HEATING SYSTEMS

Electricity is ideally suited to space heating because it is simple to distribute and easy to control. It is often the first choice where a low initial cost is the dominating factor, and it is used extensively in apartment buildings.

Most electric heating systems in apartment buildings use baseboard heating elements. Some systems, however, may use electric convector heaters, unit heaters, or low-temperature radiant panels.

Typically, space heating throughout the building is controlled by on/off thermostats situated either on the heating devices themselves (built-in thermostats) or in various suitable locations away from the actual source of heat. Where close control of temperature is desired, as is the case in apartment units, remote thermostats are preferable. A thermostat for each room is the ideal arrangement; however, as an economy measure, one thermostat may be used to control two or more rooms. Built-in thermostats may be used for other spaces in the building, such as foyers, games rooms, and storage areas.

In large open spaces where several electric heaters are required, it is desirable to control them from a single location, otherwise cross-control problems can occur. Cross control occurs when different thermostat settings cause temperature differences across the space that result in undesirable air movement. Under extreme conditions, a thermostat with a lower setting may remain permanently "off" and one with a higher setting remain permanently "on".

Most electric thermostats have a small internal heater with a fixed or adjustable heat output that is energized when the thermostat contacts close. The purpose of this heater is to provide heat anticipation; that is, it will try to compensate for the fact that, once the heating device has turned off, heat stored in the heater or in adjacent materials (wall, floor, furniture) will cause the space temperature to rise further. Low-temperature radiant panels store substantial quantities of heat; the thermostat may, therefore, shut off the flow of heat when the space temperature is considerably lower than the point selected on the control setting.

As mentioned earlier, individual space-heating controls are an effective method for matching heat supply to heating requirements. Because such controls are an integral feature of electric heating systems, these systems generally have the potential to be more energy efficient than hydronic systems controlled from a single point.

WARM-AIR HEATING AND VENTILATION SYSTEMS

Some spaces in apartment buildings — notably corridors and stairways — are heated by warm-air systems. These also provide ventilation and control the flow of air between spaces within the building. The essential components of a warm-air heating system are a fan, an air filter, a heating coil, a system of ductwork

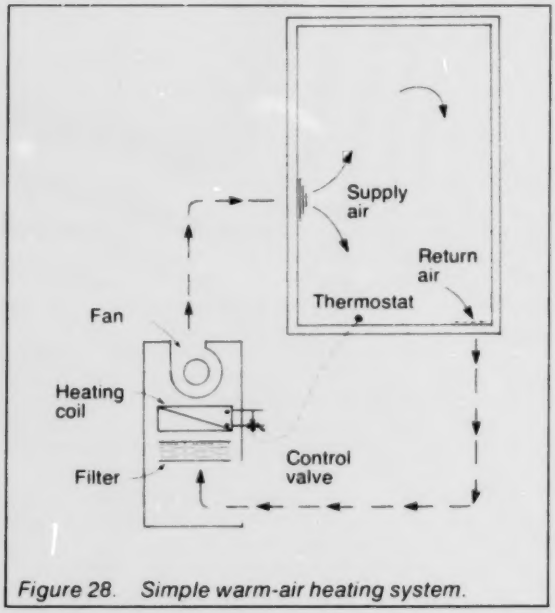


Figure 28. Simple warm-air heating system.

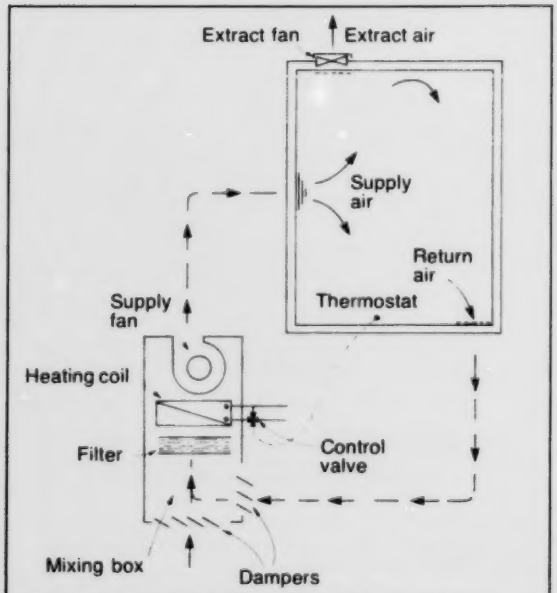
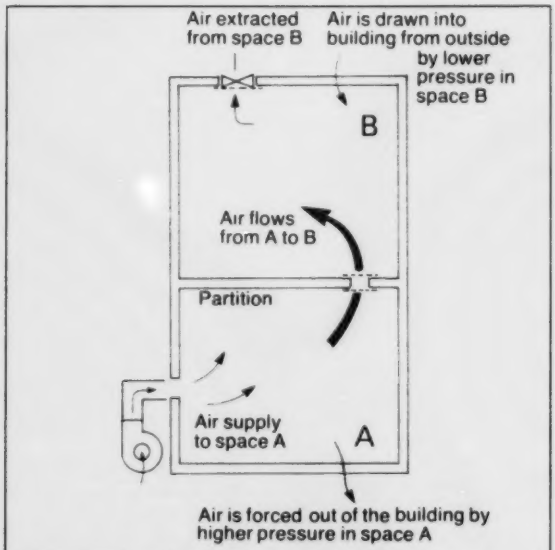


Figure 29. Simple warm-air heating and ventilating system.

and supply grilles, and a thermostat to control the operation of the fan or vary the temperature supplied to the space (see Figure 28). The addition of a fresh air supply, balancing dampers, and either a return fan or an exhaust fan (Figure 29) completes the basic warm-air heating and ventilation system. Some systems also include humidifiers, which add moisture to the air.

If air is introduced into a space or exhausted from it at a controlled rate, the flow of air can be controlled between that space and an adjacent one (assuming that the barrier between the two spaces is not airtight). The direction of flow is from high pressure to low. The working of the system is illustrated in Figure 30; its main components and their functions are described below.


Air extracted from space B
Air is drawn into building from outside by lower pressure in space B
B
Air flows from A to B
Partition
Air supply to space A
A
Air is forced out of the building by higher pressure in space A

Where flow from A to B is desired, it is normal to provide an opening in the partition. This could be a transfer grille or just a gap around a door.

Figure 30. Control of air movement between adjacent spaces.

Fans

Fans are essential to any mechanical ventilation or warm-air heating system. They are used to pump air through the ductwork system, induce outside air into or expel exhaust from the building, and create air movement within a space. Three main types of fan are: propeller, axial-flow, and centrifugal.

Propeller fans (see Figure 31) have the most simple design, but they operate at low efficiency and have limited pressure-creating capacity. They are typically used without ductwork, for example, in wall-mounted exhaust units and floor or table units.

Axial-flow fans (shown in Figure 32) are intended for duct mounting, usually in ventilation systems wi.h moderate pressure requirements. They may be fitted with guide vanes, which direct or guide air into the fan, improving its efficiency. They tend to be noisier in operation than centrifugal fans.

Centrifugal fans (Figure 33) operate on the same principle as that described for centrifugal pumps earlier, under Circulation Systems. Air is drawn into the impeller and thrown outward under the action of centrifugal force. The blades of the impeller may be curved backward or forward. Forward-curved models are used mainly in small systems requiring low or medium pressure. These fans are quiet and compact but have a rising power characteristic; that is, the motor can be overloaded if the resistance of the ductwork is insufficient for the particular fan/motor combination. To guard against overloading, oversized motors are often used. These are less efficient, however, and give a poorer power factor than a correctly sized motor. Backward-curved blade (and the refined-version aerofoil blade) fans offer good efficiency, do not overload the motor, and are capable of developing higher pressures than forward-curved fans. They are widely used in larger heating and ventilation systems.

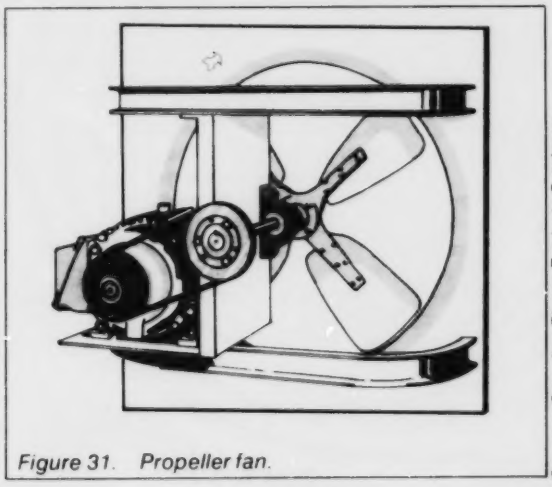


Figure 31. Propeller fan.

Courtesy Canadian Blower Products Catalogue

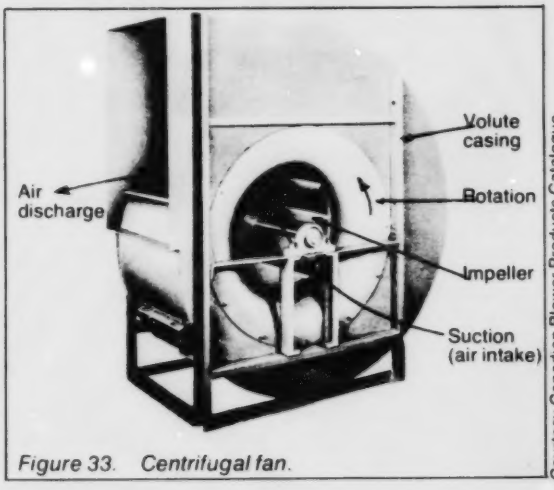


Figure 33. Centrifugal fan.

Courtesy Canadian Blower Products Catalogue

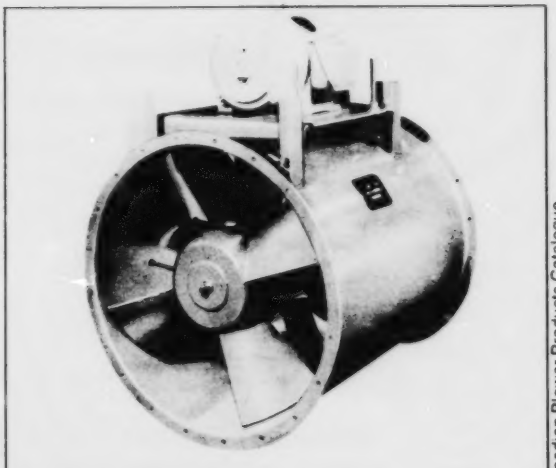


Figure 32. Axial flow fan with exterior motor. (Alternative arrangement has motor in the air stream.)

Courtesy Canadian Blower Products Catalogue

Air Filters

Air filters are used with fans and ducts to prevent the build-up of dirt within the air-flow system. Dirt on heating and cooling coils can significantly reduce their output, and on fan blades it can impair the unit's operating efficiency. Other filters may be used to cleanse the air of unpleasant odours or noxious gases.

Most dust filters work by trapping particles of dirt in

the filter medium. The efficiency of the filter tends to decrease as dirt builds up, until the point is reached at which particles will no longer adhere to the filter. As dust builds up on the filter, its resistance to air flow increases, and the air volume supplied by the fan correspondingly decreases.

There are three common types of dust filter: viscous, dry, and electrostatic. The relative efficiency of each is shown in Table 7, and differences between them are explained briefly below.

Table 7 Relative Efficiency of Dust Filters

Filter efficiency when clean*

Type	Efficiency (per cent)
Viscous	5 – 15
Dry fabric (cotton-wool pads obliquely arranged)	25
Dry fabric (cotton-wool wadding V-arrangement)	35
Dry fabric (cotton-wool wadding plus fine glass wool)	75
Electrical	50 – 90
Absolute	65 – 99.9

* Figures based on methylene-blue tests when filter is clean

Viscous Filters

The filtering medium, usually some form of metal or glass fibre, is covered with an oily fluid to help trap dust particles. Replacement or reusable cell filters or automatic-roll types (see Figure 34) are available. Viscous filters have a high dirt-holding capacity and low pressure drop, but low efficiency. They are suitable for use in industrial areas that have a great deal of atmospheric pollution.

Dry Filters

Cotton-wool, glass fibre, pleated paper, and foamed polyethylene are the materials commonly used in dry filters. The filter is usually coated with adhesive to improve its dust-collecting capability.

The efficiency of dry filters can be increased by varying their position in the air-flow system or by increasing the amount of filter material used, as illustrated in Figure 35. When a very large amount of material is used in the filter, the efficiency becomes very high, and the filter is termed "absolute".

Cell and the automatic-roll type of dry filters are also available; the automatic-roll type is shown in Figure 36. This requires little maintenance, but it is usually less efficient than other kinds.

Electrostatic Filters

Electrostatic filters impart an electrical charge to dust particles, which are then attracted to and collected on an oppositely charged collection plate. These filters offer negligible resistance to air flow, high efficiency, and low maintenance.

Adsorption Filters

The most common type of adsorption filter used in warm-air and ventilation systems is the activated carbon filter. It attracts and removes from the atmosphere objectionable smells and poisonous gases, such as sulphur dioxide. One use of this type of filter is in kitchen range hoods equipped with a recirculating fan. The filter effectively removes cooking odours, without making it necessary to exhaust large quantities of air from the room.

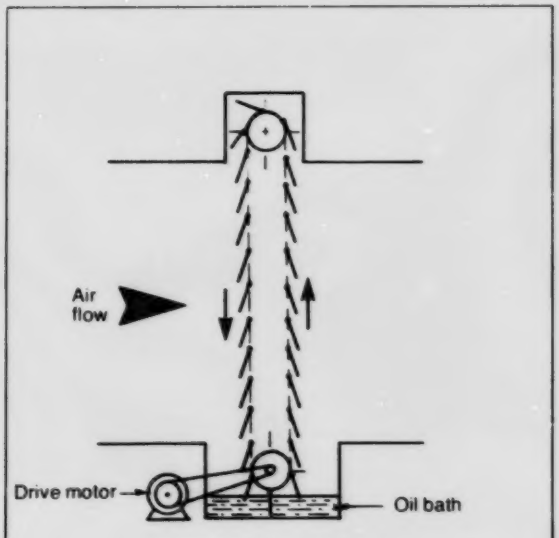


Figure 34. Automatic viscous-roll type of filter.

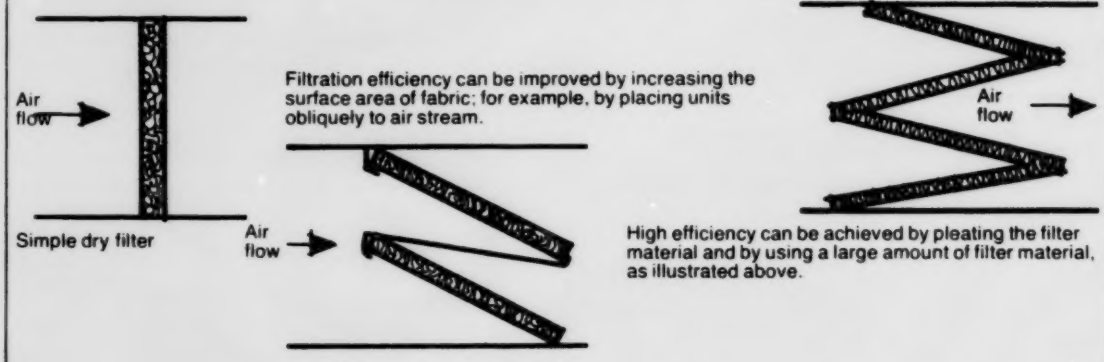

Air flow
Simple dry filter
Filtration efficiency can be improved by increasing the surface area of fabric; for example, by placing units obliquely to air stream.
Air flow
Air flow
High efficiency can be achieved by pleating the filter material and by using a large amount of filter material, as illustrated above.

Figure 35. Alternative uses of dry filters.

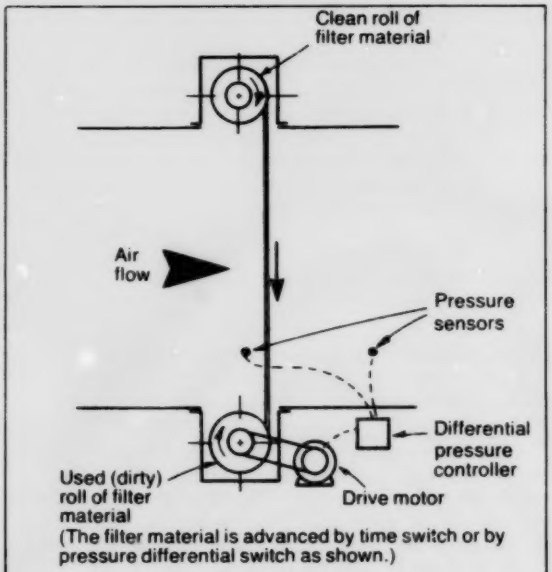

Clean roll of filter material
Air flow
Pressure sensors
Differential pressure controller
Used (dirty) roll of filter material
Drive motor
(The filter material is advanced by time switch or by pressure differential switch as shown.)

Figure 36. Automatic dry-roll type of filter.

Heating Coils

Heating coils may be electric, hot-water, or steam. Hot-water and steam coils are often described as extended surface coils; they usually consist of copper tubing and an aluminum fin, which serves to increase the heat-transfer capability of the coil.

Output from steam coils is controlled by means of a two-way on/off or modulating valve; hot-water coils can be controlled by either two-way or three-way valves. Figure 37 shows the various arrangements that can be used. The use of three-way valves with a coil circulating pump will greatly reduce the risk of coil freeze-up where the coil is used to heat cold air drawn in from outside the building. Pumps supplying water to heating coils used to preheat outside air in ventilation systems should not be shut off in subfreezing weather, even if the fan is shut off, because leakage through the outside air damper can cause freeze-up.

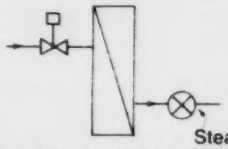
Grilles and Diffusers

Grilles and diffusers are used to supply and extract air or allow the transfer of air from one space to another. Various types are shown and briefly described in Table 8.

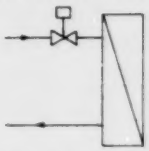
Dampers

Dampers are required to regulate the flow of air in ductwork systems, just as valves are necessary to regulate the flow of water in piping systems. There are two types of damper: balancing and control.

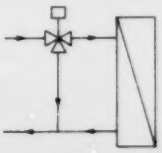
Balancing dampers are used to balance air flow within the duct system. They are normally adjusted when the air system is installed and remain fixed in order to achieve the desired distribution and mixing of air through the building. Changing the position of a single damper can affect other parts of the system; if readjustment is required, therefore, it should be done by someone who understands the system.



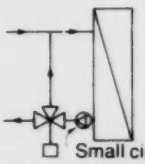
Output from steam coil controlled by throttle valve



Output from water coil controlled by a throttle valve



Output from a water coil controlled by a three-way diverting valve. Arrangement supplies constant-temperature water to coil at a variable flow rate.



Output from a water coil controlled by a three-way mixing valve. Arrangement supplies variable-temperature water to the coil at a fixed flow rate.

Figure 37. Output control of heating coils.

Control dampers are used to vary the air volume or divert or mix air streams. They open or close in response to a preselected control signal.

Humidity-control Devices

Some warm-air and ventilation systems include humidifiers, which add moisture to the air. Low humidity in a building is usually the result of excessive infiltration. To the extent that the rate of infiltration can be reduced, it may be possible to dispense with humidifiers altogether.

Dehumidifiers perform the opposite function: they take excessive moisture out of the air. As high humidity problems are usually confined to specific areas, such as bathrooms, kitchens, and laundry rooms, exhaust fans can be used to eliminate the problem.

ENERGY-EFFICIENT OPERATION

Energy consumption for heating and ventilation can be reduced in many apartment buildings through one or more of these measures:

- reduction of system loads
- improvement in the distribution of heat
- improvement in the efficiency of boilers, and
- heat recovery.

Reduction of System Loads

Temperatures and Ventilation Rates

If possible, space temperatures should be maintained at the levels recommended earlier, in Table 1. Thermostats should be installed to lower temperatures automatically when spaces are unoccupied or seldom in use (entrances, lobbies, corridors, and assembly spaces at night). Ventilation rates should be kept at the levels recommended in Table 3.

Heat Transmission

Adding insulation to walls and roofs will reduce heat loss from a building; because of the way apartments are built, however, it may be too difficult or too expensive to adopt this solution. It is nevertheless worthwhile to seek professional advice on the matter, as some improvements may be feasible.

If windows are only single glazed, consideration should be given to double glazing particularly on those windows facing within 80 degrees of North.

Leakage

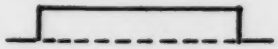
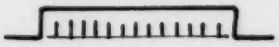
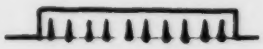
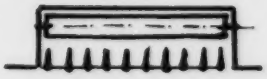
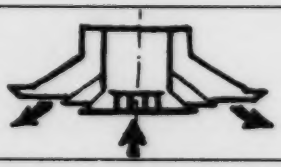
Most air leaks are between sash and window frames in openable windows, at construction joints such as window-to-wall joints and wall-to-roof/floor slabs, around doors, and through the ventilation system.

Leakage through sashes is usually a function of the window design and is not easily corrected without replacement of the window. Weather stripping should be checked and replaced if it is defective. Various types of draught excluders are available for reducing leakage through older wood sash windows.

Leakage through construction joints can usually be corrected by caulking. Infiltration through exterior doors can be reduced by ensuring that the doors have suitable draught excluders. At the main entrance, it is desirable to have a vestibule. The vestibule can project either inside or outside the building; it should not be heated.

To reduce the stack effect described under Infiltration and Exfiltration, vertical shafts passing up the

Table 8 Typical Grilles and Diffusers

Type	Diagram	Application	Comments
Perforated or stamped lattice		Exhaust or transfer	Simplest, lowest cost form of grille.
Fixed vane		Extract, transfer, or supply	Low cost. Limited use as supply grille to large temperature differentials and short throws.
Aerofoil vane. One row of adjustable louvres		Supply or extract	Frequently used grille. Direction control in a single plane.
Aerofoil vane. Two rows of directional louvres		Supply	Gives complete direction control (i.e., in two planes).
Linear diffuser		Supply or extract	Commonly used in side wall, window and floor applications. High air volume handling with minimum grille area.
Diffuser fixed cones		Supply or extract	Common form of ceiling outlet in air-conditioning systems. Can provide large air volumes without creating drafts.
Diffuser adjustable cones		Supply	
Diffuser supply and extract		Combined supply and extract	Source: IHVE Guidebook B, 1970.

building should be sealed at intervals. For example, vertical electrical and pipe shafts could be sealed at every fourth level. Open stairwells should be provided with self-closing tightly fitting doors, and solid walls, to effectively cut them off from circulation spaces.

To prevent or reduce leakage through the ventilation system, some form of draught control should be incorporated to close off the system automatically when the fan stops operating. One common device, used in central ventilation systems and with individual exhausts, is the gravity damper (see Figure 38), which closes under its own weight and will not blow open. Sealing strips around the damper reduce leakage but do not eliminate it entirely.

Gravity dampers are also used on larger central ventilation systems. In this case, the damper may be composed of several smaller dampers, which fall under their own weight. This is the least preferred method as these dampers can be opened by the negative pressure on the leeward side of the building or by the pulsating action of the wind. The weight must not be so heavy that it prevents the dampers from opening when the fan is switched on. Even with such devices, leakage through the dampers, which often rely on metal to metal seal, is usually quite high. The problem can be particularly serious in tall buildings with vertical ventilation stacks. Leakage can be reduced by installing a good quality multi-blade damper with seals on the ends and edges of the blades. A motor can be used to open and close the damper according to the fan operation (see Figure 39).

Even when the ventilation fans are operating, the variation in pressure induced by winds and stack action will superimpose itself over the pressure developed by the system fans. For very tall buildings with central fan systems and vertical ventilation shafts, the ventilation rate can vary with changes in wind and outside temperature. Such an effect can be confirmed by taking air-flow measurements in the main ductwork under various weather conditions. If the variation is considerable it might be worthwhile providing automatic fan control to maintain a constant ventilation rate.

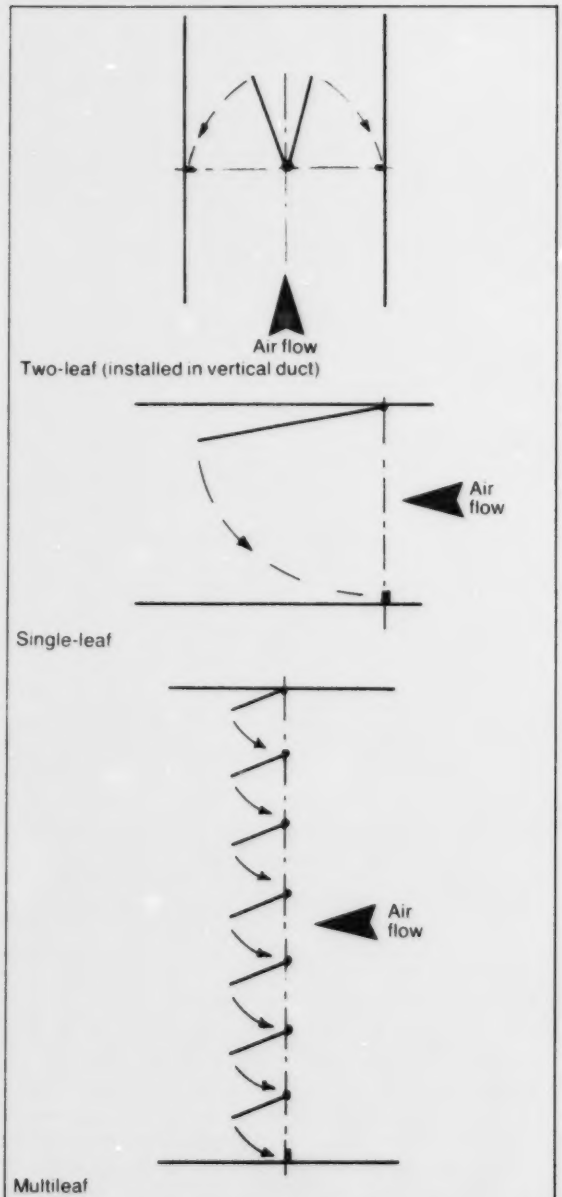


Figure 38. Simple "backdraft" gravity dampers.

Ventilating Mechanisms

Most ventilation systems are installed to handle the maximum load; consequently, they over-ventilate under other conditions. This is particularly true of systems for bathrooms, kitchens, garages, and swimming pools.

Centrally controlled apartment extract systems can be shut off during the night for kitchen, bathroom, and corridor areas. Ventilation of laundry rooms, exercise rooms, and other assembly areas should be shut off

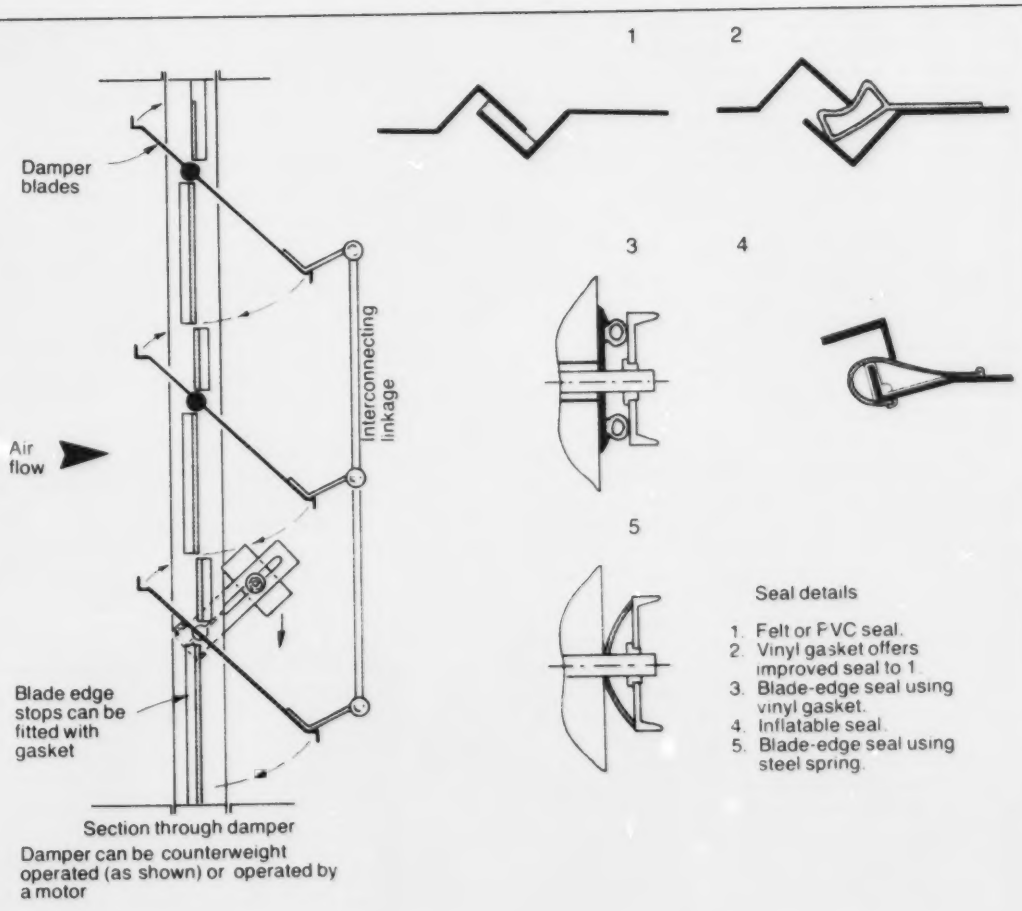


Figure 39. Typical low-leakage damper construction

when the space is not in use.

Ventilation of swimming-pool halls is primarily intended to keep the relative humidity to an acceptable limit; these systems have to operate even when the pool is not in use. The ventilation system for this area should be controlled by a humidistat, which will reduce the number of hours that the ventilation system must operate. In conjunction with such a system, a continuously operated mechanical dehumidifier may be used.

In garages, it should not be necessary to maintain a high ventilation rate throughout the day. Carbon monoxide sensors can be installed to turn on the ventilation equipment only when the maximum permissible carbon monoxide level is reached. (This measure can result in a double saving: energy used to operate the ventilation system and energy needed to provide adequate heating in cold weather.)

Discharging building extract systems into the garage is another way of reducing the cost of heating and ventilation — provided that local regulations do not prohibit this practice. Any odours exhausted into the garage will be dissipated through dilution.

Improvement in the Distribution of Heat

The first, if obvious, requirement is that all pieces of equipment, including controls, must work correctly. Simple checks for various types of equipment are set out in Chapter 3. The operator must understand the operation of the system and each of its components. Once these conditions have been met, a number of energy-saving techniques can be applied.

Insulation of Equipment

Insulation of hydronic or steam heating equipment can reduce heat loss and prevent overheating within the building. Pipework, boilers, and heat exchangers can all be insulated.

Insulate and seal leaks in ductwork. As with pipework, it is more important to insulate and seal leaks in unheated spaces.

Reduction of Water Flow and Resistance

The rate at which water flows through a hydronic heating system depends upon the performance of the pump and the amount of resistance that exists in the pipework. When a heating system is designed, it is not possible to predict precisely the resistance of the pipework. A margin is allowed, which usually results in a rate of flow that is higher than necessary to heat the building. In many cases, it will be possible to reduce the speed at which the pump operates without lowering the output of the system below a minimum comfort level.

Pump speed can be reduced by replacing the existing motor with one of lower speed or by reducing the size of the motor sheave on belt-driven pumps (see Figure 40). Where such speed reductions are not practical, the pump impeller may be changed or the existing one turned down. None of these changes should be made unless the pump manufacturer, or another qualified person, has first been consulted for advice.

Reduction of Air Flow and Resistance

Warm-air heating systems are designed in much the same way as hydronic systems: the fan and ductwork operate in accordance with actual levels of resistance. Reducing the fan speed will result in lower system losses and air flow with subsequent power savings. Lowering the system resistance *without* reducing the fan speed will simply increase the air flow and power consumption. In the case of forward-curved centrifugal fans, the result could be overloading of the motor.

Resistance may be reduced by:

- replacing existing filters with ones that offer less resistance
- removing preheat coils if they are not essential to the operation and if there is no danger of freeze-up
- removing unnecessary dampers
- increasing the temperature of the supply air to allow a reduction in air volume.

Control of Space Temperature

Any heating system that does not incorporate individual control devices for space heating offers potential for improvement. The most common methods of control in hydronic systems have already been discussed. In ascending order of efficiency, they are:

1. Boiler-mounted thermostat;
2. "Representative" single-space thermostat;
3. Outside reset control;
4. Outside reset control with wind and/or solar compensators; and
5. Individual room control.

If either of the first two control methods is now in use in a building, the system should be upgraded to at least the third, an outside reset control. If this method is already in use and overheating is still a problem, it is worth experimenting with the reset ratio. The best way of improving comfort, however, is to install compensators or individual room thermostats.

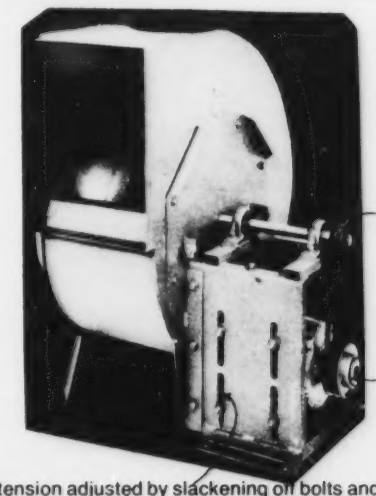

Fan sheave
Motor sheave
Belt tension adjusted by slackening off bolts and moving motor up or down. Shorter belts may be required if a smaller sheave is fitted
Courtesy Canadian Blower Products Catalogue

Figure 40. Reduction of fan speed on belt-driven pump.

The potential for improvement in electric heating systems is somewhat limited. In many spaces that do not have their own thermostats and are subject to overheating, additional controls may be installed. The major potential saving, however, is to change from a single meter to individual tenant meters, which will require tenants to pay for the electricity they use. Although it could be costly to rewire the existing system for individual meters, studies indicate that the saving in consumption can be substantial (as high as 35 per cent).

Boiler Efficiency

It is first necessary to ensure that the boiler is in peak operating condition. It should not be "overfired",[3] the air-to-fuel ratio should be correctly set, heat-transfer surfaces should be clean, gaskets and insulation should be in good condition, and the boiler and burner controls should be operating correctly. Chapter 3 describes the checking procedures to be carried out; measures for improving the efficiency of boiler operation are outlined below.

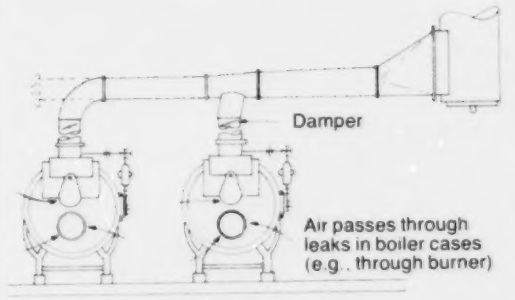
Multiple Boiler Installations

Some heating systems are served by more than one boiler. It may be advantageous to install sets of valves that will permit isolation of off-line boilers from the main system. Then, during periods of mild weather or in the event of reduced heating demand, supplementary boiler units can be shut off, without disrupting the rest of the system. If it is expected that the boiler will be brought back into use after a temporary shut-down, a very small flow of warm water can be maintained through the boiler (by means of bypass valves and a regulating orifice); this precaution will reduce the heat loss of idling boilers and avoid the risk of thermal stress when the boiler is brought back on line. Part-load efficiency of a multiple boiler installation can also be improved by having the various units operate in sequence, according to heating demand.

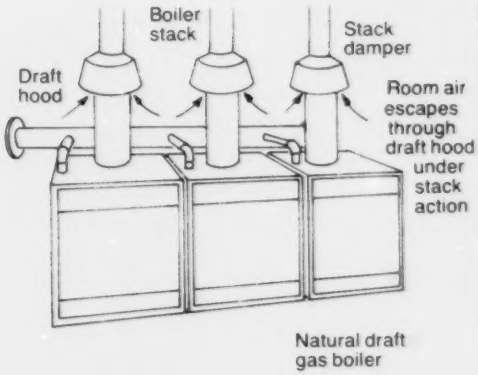
Where permitted by codes, a damper should be installed between an off-line boiler and the boiler stack, to prevent cold air from leaking back into an unheated boiler or warm air leaking through it and out of the flue (see Figure 41). The damper should remain closed as long as the boiler is not in use. For gas boilers equipped with atmospheric burners, vent dampers prevent the flow of room air up through the vent hood.

Blowdown Losses

Periodically water must be bled from steam boilers to prevent a build-up of residue in the unit. This process (called blowdown) results in loss of heated water and increased energy consumption as the replacement water is heated. The operator should determine the rate of build-up in the boiler and bleed it only when necessary.



Damper eliminates air flow through the boiler when the boiler is not firing



Damper eliminates flow of room air through draft load of natural draft boilers

Figure 41. Damper.

[3] A boiler is said to be "overfired" if it has a relatively low ratio of heat-transfer surface area to boiler output.

Domestic Hot-water Supply

If domestic hot water is heated by the main boiler in a hydronic system during the summer months, when space heating is not required, it is wasteful to use the main unit for this purpose only. A more economical method is to install a separate small boiler with sufficient capacity to satisfy hot-water needs. Then, for four or five months of the year, the main boiler system can be shut down.

Replacement of Boilers and Burners

If boilers or burners are nearing the end of their useful life, or if their full-load or part-load efficiency is relatively poor compared to that of modern equipment, it may be worthwhile to replace or modify them. Possible changes include:

1. Providing electronic ignition for gas burners currently equipped with pilot light ignition;
2. Exchanging atmospheric burners for power burners;
3. For a single-boiler installation with on/off or high/low firing, fitting a modulating burner, or replacing the single-boiler with two smaller boilers with high/low fire or modulating control;
4. Replacing a single-boiler with a modular boiler system — that is, several low-capacity boilers — usually of low thermal mass and equipped with on/off burner control; by operating only the requisite number of boilers to meet the load, total boiler plant efficiency can be maintained over a wide range of heating demand.

When a boiler is replaced, the new one should be able to meet the load that will be placed on the system during periods of maximum demand. In Ottawa, a boiler sized at 150 per cent of peak demand operates below 40 per cent full output for 97 per cent of the time. Operation of such a unit is inefficient, compared with that of smaller equipment, and it results in unnecessarily high energy costs. This, of course, will vary with location.

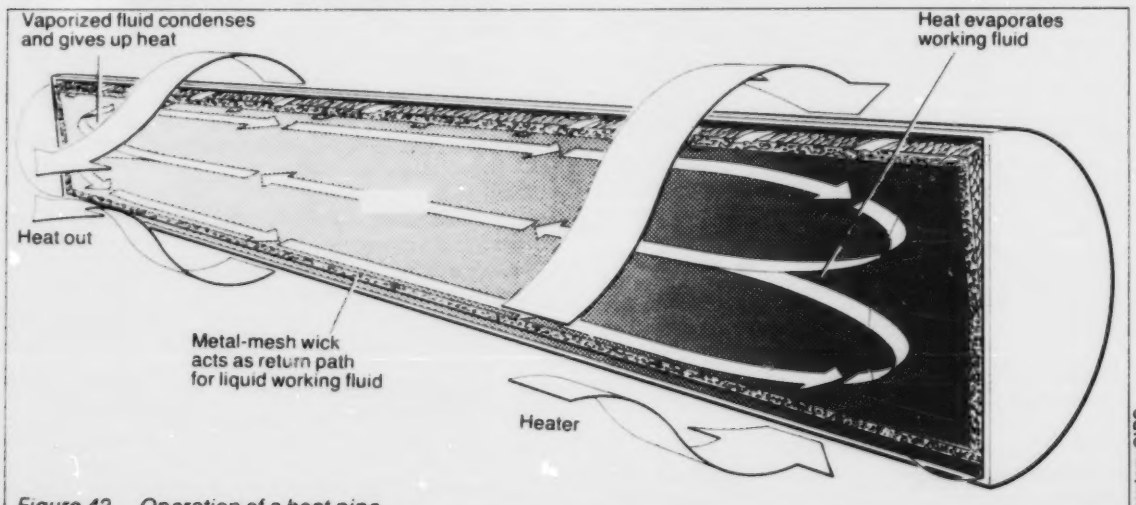
Heat Recovery

A variety of equipment is available for recovering heat from various air, water, flue-gas and refrigerant systems in a building. Heat-recovery systems can be split into two main categories: those that use a heat exchanger to pass heat directly from one fluid to another; and those that rely on heat pumps to capture low-grade heat and raise its temperature.

Heat pumps are described under Heating Systems, Heat Pumps. Equipment that incorporates heat exchangers is discussed briefly below.

Heat Pipes

A heat pipe is a sealed tube containing a wetted wick. If heat is applied to one end of the heat pipe, the liquid in the wick evaporates and the vapour flows to the cooler end of the tube, where it condenses. The condensed vapour is then returned to the warm end of the tube by wick action (see Figure 42). A heat-pipe system (Figure 43) consists of several such tubes and typically is used to transfer heat from one air stream to another.


Vaporized fluid condenses and gives up heat
Heat evaporates working fluid
Heat out
Metal-mesh wick acts as return path for liquid working fluid
Heater

Courtesy CIBS

Figure 42. Operation of a heat pipe.

Thermal Wheels

A thermal wheel is a revolving cylinder packed with an air-permeable, heat-absorbing medium, such as metal turnings. Like the heat-pipe system, the wheel must span two adjacent ducts. As the wheel rotates, it absorbs heat from the warmer duct and transfers it to the cooler one (see Figure 44).

Air-to-air Plate Heat Exchangers

The air-to-air plate heat exchanger, shown in Figure 45, relies on steel or impregnated paper to transfer heat between the warmer and cooler air streams.

The three types of equipment described above are normally used to transfer heat from exhaust air to fresh air. They may, for example, serve to transfer heat from a centralized apartment unit extract system to a corridor, or between garage supply and exhaust ducts must be adjacent. Where the two ducts are not close together, a run-around system can be used.

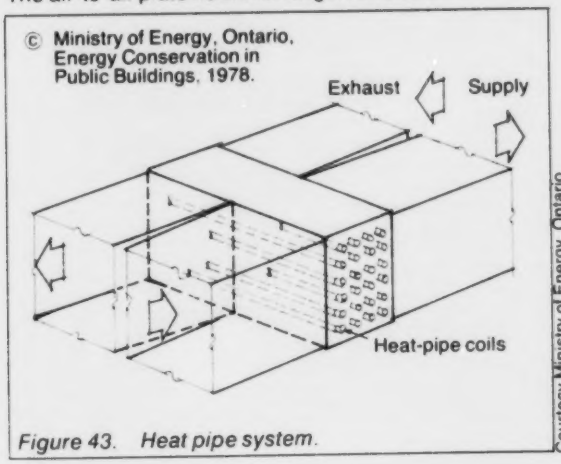


Figure 43. Heat pipe system.

Courtesy Ministry of Energy, Ontario

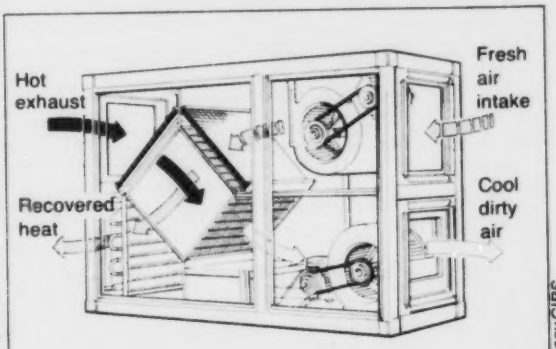


Figure 45. Air-to-air plate heat exchanger.

Courtesy CIBS

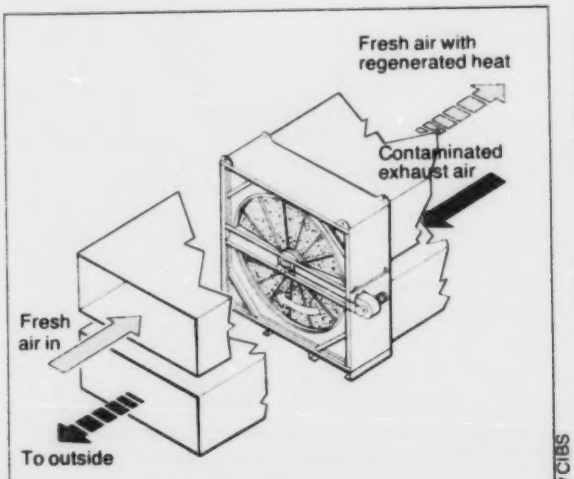


Figure 44. Thermal wheel heat exchanger.

Courtesy CIBS

Run-around System

A run-around system includes two extended surface coils, one situated in a warm air stream, the other in a cold. The two coils are connected by piping. A small pump is used to circulate a fluid (usually glycol and water) between the two coils, transferring heat between the two air streams (see Figure 46).

Shell and Tube Heat Exchangers

A shell and tube exchanger, together with other forms of liquid-to-liquid heat exchangers, can be put to a variety of uses. Potential heat sources include:

- blowdown from steam boilers (may be used to preheat replacement water)
- condenser water from refrigeration equipment
- hot refrigerant gas
- steam condensate that would otherwise run to waste
- laundry waste water (may be used to preheat domestic hot water), and
- boiler flue gas heat exchangers. (Special air-to-water heat exchangers can be installed in the boiler flue. The reclaimed heat may be used for preheating

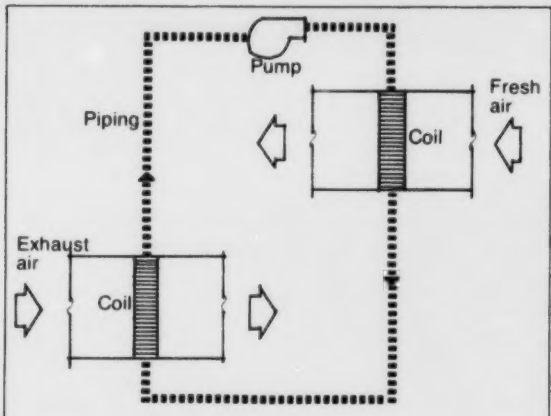
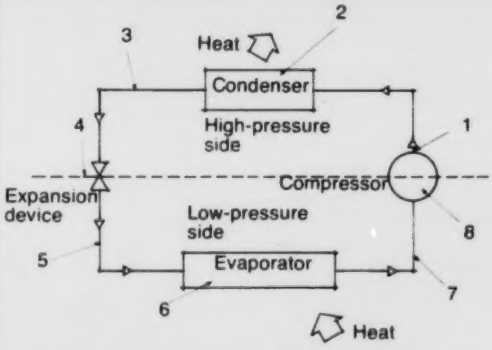


Figure 46. Glycol run-around system.

Courtesy Ministry of Energy, Ontario



1. Hot gas leaves compressor at high pressure
2. Hot gas condenses in condenser, giving off heat to surroundings
3. Hot liquid at high pressure
4. Liquid expands
5. Cold liquid refrigerant
6. Liquid refrigerant evaporates, absorbing heat from surroundings
7. Cool low-pressure vapour enters compressor
8. Vapour is compressed

Figure 47. Basic operation of a vapour compression system.

combustion air or domestic hot water, or for warming ventilation air).

AIR-CONDITIONING SYSTEMS

Most air-conditioning systems installed in multi-unit buildings rely on vapour compression to generate a supply of cool air. A vapour compression system makes use of a fluid that boils at a low temperature; this fluid is normally referred to as a "refrigerant". The operation of a simple refrigeration process is explained in Figure 47.

An air-conditioning system based on vapour compression has four main components: a compressor, an evaporator, a condenser and an expansion device.[4]

Compressors

There are two common types of refrigeration compressor: reciprocating and centrifugal. Reciprocating compressors are often used in small and medium-sized systems. Their operation is not unlike that of a car engine: refrigerant is drawn into a cylinder on the downward stroke of the piston and compressed on the upward stroke.

Centrifugal compressors operate on the same basic principle as that described for centrifugal pumps and fans. They are frequently used in larger systems.

Evaporators

An evaporator can take the form of a cooling coil, which cools the air through evaporating the liquid refrigerant. A system that works in this way is called a direct expansion system. It is commonly used in small air-conditioning units. If the refrigerant is first used to cool water, which is then piped to the cooling coils, the system is referred to as an "indirect system" and the refrigeration machine is usually called a "chiller".

Condensers

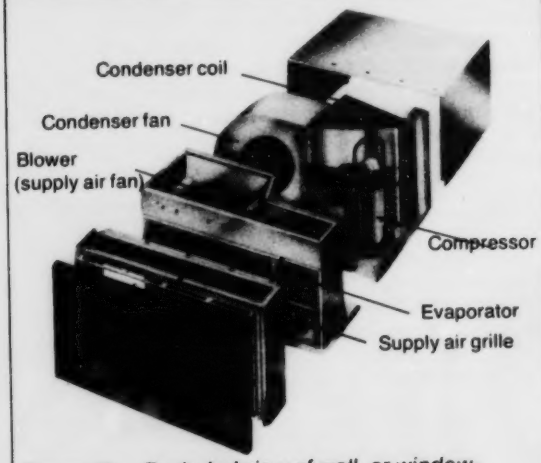
The purpose of the condenser is to condense the hot refrigerant vapour by cooling it; the refrigerant is then passed back to the evaporator. Cooling may be effected by air, water, or water and air combined. With units that use water cooling, a recirculating system is frequently set up, in which water leaving the condenser is cooled by a cooling tower.

Air-conditioning Units

Individual Room Units

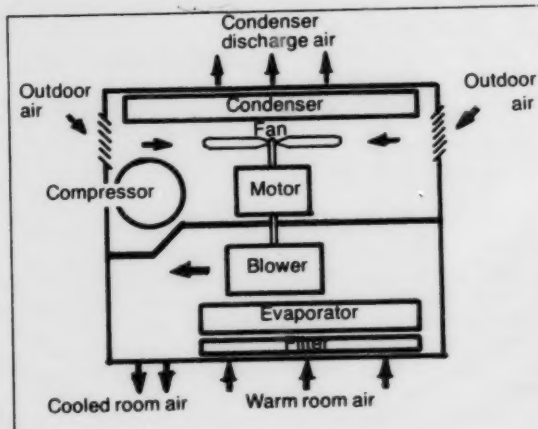
Individual units, shown in Figures 48 and 49, may be mounted in the window or wall of a room. These units usually contain an adjustable built-in thermostat which will cycle the compressor on and off to provide the necessary cooling. Some units have two-speed or three-speed fans; the speed is selected manually or controlled by the thermostat.

[4] Heat-pump systems, which may also be used for air cooling, have been covered in an earlier part of this section. For an explanation of their operation, see under Heat Pumps, Chapter 2.



Courtesy Electricity Council, U.K.

Figure 48. Exploded view of wall- or window-mounted room unit.



Courtesy ASHRAE

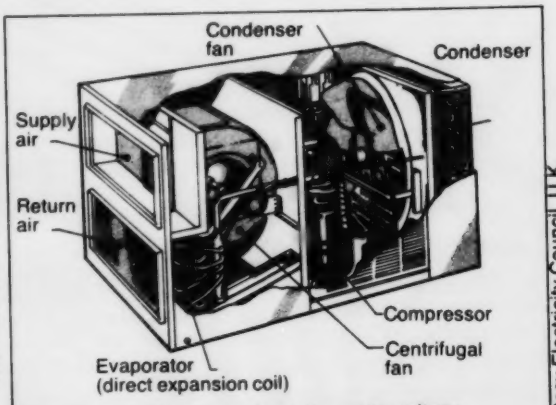
Figure 49. Schematic view of room air-conditioner.

Individual Apartment Units

Apartment units are essentially a bigger version of the room unit, with a fan capacity capable of supplying air through a system of ducts. The unit, which is controlled by the occupant of the apartment, may be mounted in a wall or window; or a remote condenser may be used so that the unit can be located anywhere in the apartment.

Remote Units

Figure 50 shows a typical remote air-conditioning unit. It is mounted outside the space it serves, usually on a roof. A system of ducts is connected to the unit to supply and return air.

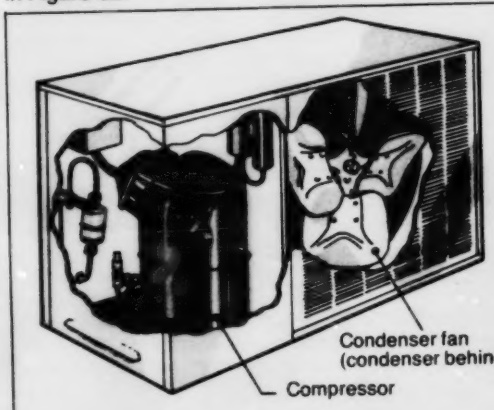


Courtesy Electricity Council, U.K.

Figure 50. Cut-away view of remote unitary air-conditioning unit.

Condensing Units

A condensing unit is designed for a location remote from the space being cooled and independent of the fan system. A typical unit, containing a compressor and air-cooled condenser, is shown in Figure 51. A condensing unit is often used in conjunction with a room-mounted or duct-mounted fan-coil unit, illustrated in Figure 52.



Courtesy Electricity Council, U.K.

Figure 51. Condensing unit.

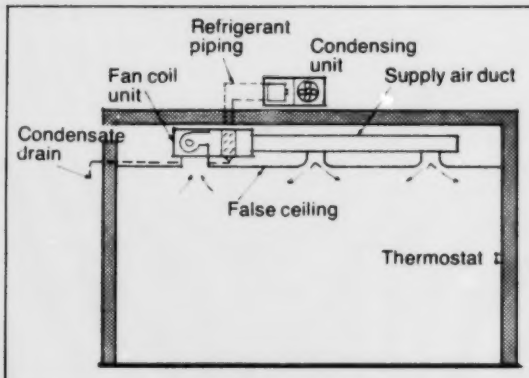


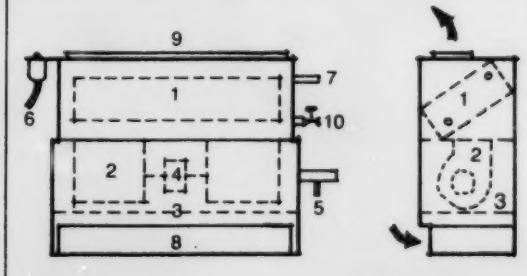
Figure 52. A roof-mounted condensing unit with ceiling-mounted fan coil unit and ducting.

Courtesy Electricity Council, U.K.

Chilled-water Systems

Cooling in all the systems described above results from the direct expansion of liquid refrigerant into the cooling coil. In a chilled-water system, or indirect system, chilled water is produced at a central location by a "chiller" and circulated through pipework to cooling coils located in air-handling equipment. A typical system commonly used for apartment cooling consists of a central chilled-water system supplying chilled water to individual-room fan-coil units. (The fan-coil units may contain a heating coil for winter operation.)

The fan-coil configuration shown in Figure 53 is for a room unit. Wall mounting or horizontal ceiling mounting may be used. The output of the fan coil can be controlled by either return air or space-mounted thermostats, which regulate the supply of water or cycle the fan on and off. Where on/off fan control is used, a space-mounted thermostat is recommended, to give a reliable reading of space temperature.



1. Finned tube coil
2. Fan scrolls
3. Filter
4. Fan motor
5. Auxiliary condensate fan
6. Fan speed-control switch
7. Coil connections
8. Return air opening
9. Discharge air opening
10. Water-control valve

Figure 53. Typical fan-coil unit.

Courtesy ASHRAE

ENERGY-EFFICIENT OPERATION

Some of the general energy-conserving measures described in the section on heating — for example, reducing infiltration and sealing leaks in ductwork — are equally applicable to air-conditioning systems. Other measures specifically applicable to air-conditioning systems are dealt with below.

Effects of Sun and Outside Air

Solar heat entering through windows can be reduced by the use of curtains or blinds. Units in low-rise buildings may be shaded by trees.

Window-mounted and wall-mounted units should be sealed to prevent the infiltration of outside air. They should never be operated when windows and outside doors are standing open.

If the air-conditioning system draws in outside air in its operation, an economizer cycle can be used to reduce the cooling load. The working of the cycle is illustrated in Figure 54.

Adjustment of Evaporator Temperature

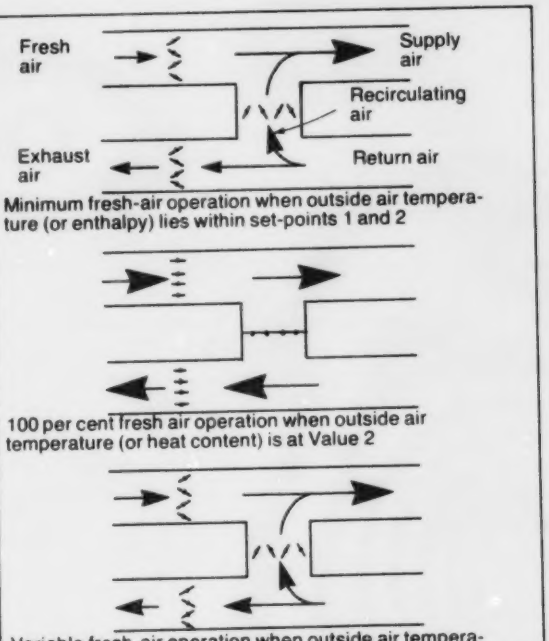
The performance of a refrigeration machine can be increased by raising the temperature of the evaporator. (For reciprocating chillers the performance should increase 2 per cent per degree rise in evaporator temperature, and for centrifugal machines by 3 per cent per degree rise.) For chilled-water systems, the cooler the weather, the higher the water temperature can be set. The temperature can be reset daily, weekly, or monthly, or be set permanently higher throughout the cooling season.

Multiple Chiller Installations

If a chilled-water system includes two or more chillers, the equipment should be run sequentially, as demand requires. Off-line equipment should be isolated from the main system.

Cooling Towers

Cooling towers can consistently provide a lower condensing temperature than can air-cooled condensers.


Fresh air
Supply air
Recirculating air
Exhaust air
Return air
Minimum fresh-air operation when outside air temperature (or enthalpy) lies within set-points 1 and 2
100 per cent fresh air operation when outside air temperature (or heat content) is at Value 2
Variable fresh-air operation when outside air temperature (or heat content) lies within set-points 1 and 2
Per cent of fresh (outside) air
1
2
Outside air temperature (or heat content)

Outside air can be used when its heat content is less than that of the returning air stream. If temperature controllers are used instead of heat-content controllers, the upper set-point temperature 2 is normally set 2 or 3 degrees below the return air temperature. It is assumed that the outside air will be more humid than the return air and will therefore require additional energy for dehumidification.

Figure 54. Outside air economizer cycle.

Lowering the condensing temperature significantly improves refrigeration machine performance.

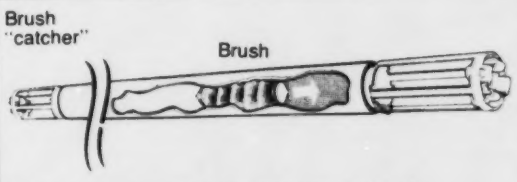
Coordination of Systems

All systems should be checked to ensure that heating and cooling do not occur simultaneously. In most instances, the heating system, including all circulating pumps, should be shut off before air-conditioning equipment is turned on for the season.

Operation of the air-conditioning system should also be coordinated with outside weather conditions. On days when cooling is not required, refrigeration equipment, including pumps, should be shut off.

Cleaning Devices

Automatic tube cleaners can be installed in condensers (see Figure 55). Clean tubes allow the equipment to operate efficiently; that is, condensation takes place at a lower temperature than it does if the tubes are not clean. Other maintenance procedures are recommended in Chapter 3.



A free floating brush is installed in each tube. A four-way reversing valve is used periodically to reverse the flow in the tubes, causing the brush to pass down the tube.

Figure 55. Automatic brush-cleaning system for condenser tubes.

Courtesy Water Services of America Inc.

DOMESTIC HOT-WATER SYSTEMS

Domestic hot-water systems consist of a water heater, piping, and a circulating pump. Some systems provide for instantaneous heating; but in apartment buildings, where the demand for hot water fluctuates throughout the day, water is preheated and stored in the water heater until it is drawn off.

There are two types of heater: direct and indirect. The first is equipped with an integral source of heat, such as an oil or gas burner or an electric element. The second derives heat energy from an external source, such as a boiler or a solar collector. In this case, the heater is equipped with a water-to-water heat exchanger.

The circulating pump maintains a constant supply of hot water within the system. Without it, water in the piping would cool during periods of light use. The pump may run continuously, or it may be regulated by an immersion thermostat. The thermostat is set to start and stop the pump within a range of 10°C; for example, at a setting of 50°C, the pump is started when the water temperature reaches 45°C and stopped at 55°C.

ENERGY-EFFICIENT OPERATION

As with other systems, the first requirement in ensuring energy efficiency is to see that the equipment is in good working order. A list of items to check is given in Chapter 3.

Adjustment of Supply Temperature

Many systems heat the water to temperatures higher than required for domestic use. In general, 49°C is satisfactory. If the temperature setting is higher than this, it should be lowered.

Reduction of Operating Time

Some energy savings can be achieved by shutting off the pump overnight. Late users may have to wait for hot water to travel through the system (as cooler water in the pipes must first be run off), but the inconvenience should be minor.

Heating Considerations

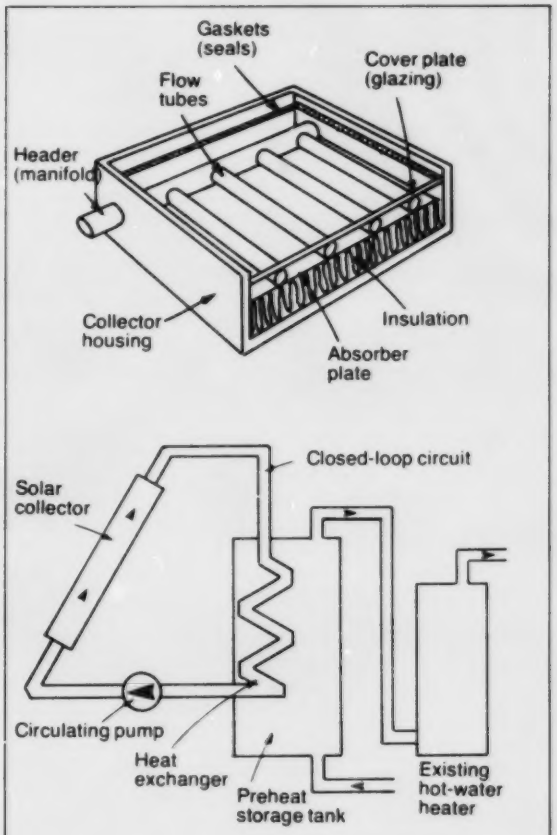
It may be possible to increase the operating efficiency of the water heater. Many of the suggestions given for boiler equipment may be applied in this case as well.

Insulation of hot-water pipes will reduce the loss of heat throughout the system.

Various heat-recovery techniques may be applied (see under Heat Recovery). In addition, solar-heating equipment can be installed. The system, illustrated in Figure 56, is not unduly complex.

Reduction of Water Flow

Plumbing equipment in many apartment units is designed to provide water at a high flow rate. Devices can be installed to cut the flow by as much as 50 per cent. These include low-flow shower heads (see Figure 57), flow restrictions (installed between the shower head and the supply pipe), and faucet aerators. If the pressure in the water main supplying the building is excessively high or fluctuates widely, an automatic pressure-reducing/regulating valve may be installed at the main.



Flat plate solar collectors can be used for preheating the cold water fed to a domestic hot-water system.

The collectors convert sunlight (solar radiation) into heat energy. Solar energy passes through the glass cover plate of the collectors and is absorbed by the absorber plate.

A closed loop circuit containing a water-antifreeze mixture is used to transfer the heat from the collector to a preheat storage tank. A small pump is used to circulate the water-antifreeze mixture around the loop.

The preheat tank is connected in series with the existing hot-water heater. Cold water make-up to the domestic hot-water system first passes into the preheat tank where it is heated by the loop heat exchanger.

Figure 56. Solar domestic hot-water heating.

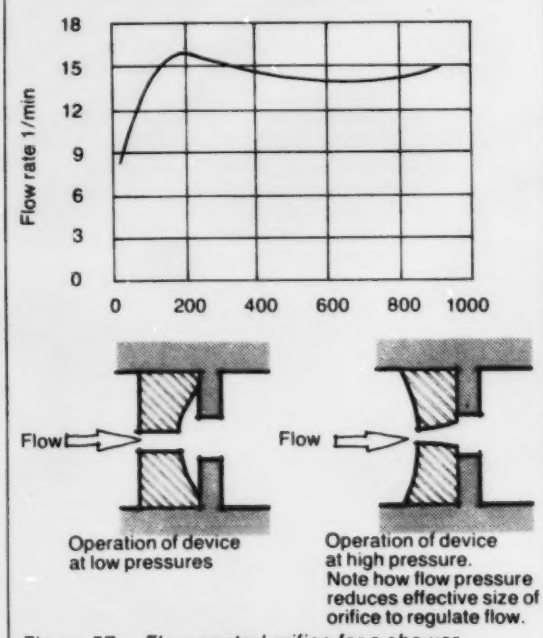


Figure 57. Flow control orifice for a shower head.

Courtesy Heating, Plumbing and Air Conditioning Magazine, U.S. (HPAC)

ELECTRICAL SYSTEMS

Electricity accounts for 55 per cent to 60 per cent of total energy use in multi-unit buildings that are not equipped with electric heating. At current rates, expenditures on this source account for a significant portion of the total energy bill.

Charges for electricity are usually made on the basis of two metered values: kilowatt-hours (kW·h) of electricity used, and kilowatt (kW) or kilo volt-amp (kVA) of demand. In order to explain these values, it is necessary first to describe the relationship between voltage and current in an electrical circuit.

All electrical-power distribution systems in buildings are alternating current systems (AC); that is, the current flow is not steady, but is continually cycling. Voltage cycles in a similar manner, but not necessarily in phase with the current. The difference between the two cyclical patterns can be represented mathematically and expressed as a "power factor". Electrical power is the quantity arrived at by multiplying current, voltage, and power factor. Electrical energy is the product of electrical power and time.

A kilowatt-hour meter records electrical energy, that is, the integration of the product of voltage, current, and power factor with time. It may be combined with a demand meter (shown in Figure 58), which measures the average demand over a short period (usually twenty minutes, although this can vary among utilities). Billings are based on the "maximum demand" in each month; that is, on the highest rate of kW·h (or kVA·h) consumption in predetermined (twenty-minute or other defined) period. At the end of each month, the demand meter is usually reset to zero.

It is important to determine whether the meter for a building is a kVA meter or a kW demand meter. If it is a kVA meter or if the utility charge is on some other basis for a poor power factor it may be worthwhile to improve the power factor of the installation. This is discussed in more detail below.

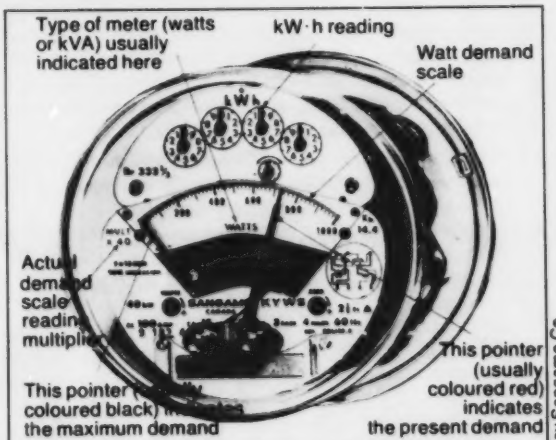

Type of meter (watts or kVA) usually indicated here
kW·h reading
Watt demand scale
This pointer (usually coloured red) indicates the present demand

Figure 58. Combined kW·h and watt demand meter.

Courtesy Sangamo Co.

ENERGY-EFFICIENT OPERATION

Lighting Systems

Reduction of Load

The lighting level in a space and the load placed on the electrical system depend upon the output from the lamp, the efficiency of the lighting fixture, the distribution of light from the fixture, the location of the fixture, the shape and size of the space, and the reflecting capability of room surfaces. As a first step towards

energy conservation, illumination should be maintained at the levels recommended in Table 2 (see under What Is Energy-efficient Management?), provided, of course, that these meet the minimum requirements set out in local codes.

Other measures include:

1. Selection of efficient light sources and fixtures. The relative efficiency of various sources of electrical light is depicted in Figure 59. Fixtures should be designed to direct light to areas where it is needed.
2. Location of the fixture in the most advantageous position. The source of light should be placed directly in the area to be illuminated.
3. Planning of the space to be illuminated. Large areas can be lighted more efficiently than small ones, as walls and partitions absorb light from a fixture.
4. Increasing the effect of lighting. The colour and cleanliness of surfaces within the room affect the amount of reflection that can be obtained from an electrical source. Light clean surfaces are recommended. Also, fixtures and lamps should be kept clean and dust-free. Figure 60 shows the effects of good maintenance.

In addition to these general suggestions, the following specific improvements should be made:

a) Replace yellowed and inefficient lens covers. This change is cost effective only if it allows a reduction in the installed lamp wattage.
b) Remove lamps in fixtures that produce more light than is required. Note that in fluorescent fixtures, the ballast will continue to consume around 20 W if not disconnected, and also, that a single tube cannot be removed in series two-lamp fixtures without extinguishing the second tube.
c) Remove unnecessary fixtures.
d) For a series fluorescent lamp fixture, rewire two fixtures from a single ballast to reduce light and power by 50 per cent.
e) For a series fluorescent two-lamp fixture, install a shorting tube in place of one of the lamps. The shorting tube looks similar to a regular tube, except that it draws no power; it simply completes the series circuit, enabling the second lamp to light. Light output and power requirements will be cut by about 50 per cent by this modification.
f) Alternatively, for a series fluorescent two-lamp fixture, install a phantom tube in place of one lamp. Like the shorting tube, it looks like a regular lamp, but maintains electrical continuity to the second tube through a capacitive element instead of an electrical conductor. This change can achieve a reduction of 67 per cent for both light and power.
g) Replace existing ballast with high-efficiency type.

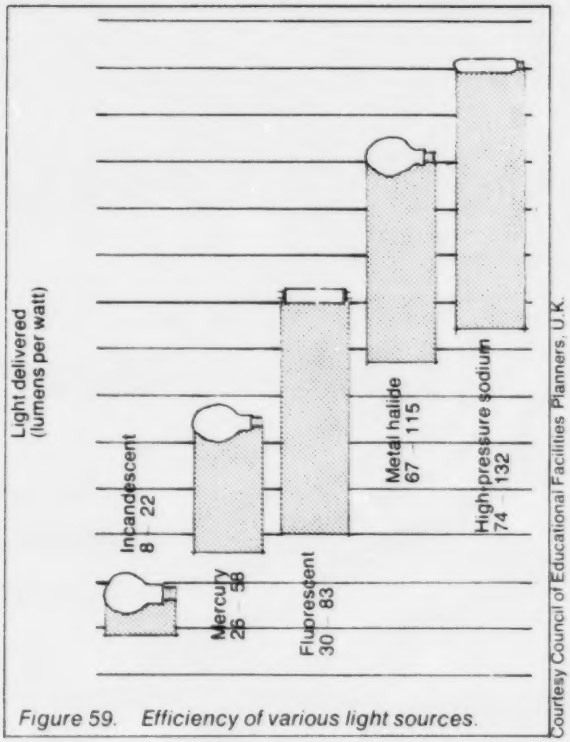

Light delivered (lumens per watt)
Incandescent 8 22
Mercury 25 58
Fluorescent 30 83
Metal halide 67 115
High pressure sodium 74 132
Courtesy Council of Educational Facilities Planners, U.K.

Figure 59. Efficiency of various light sources.

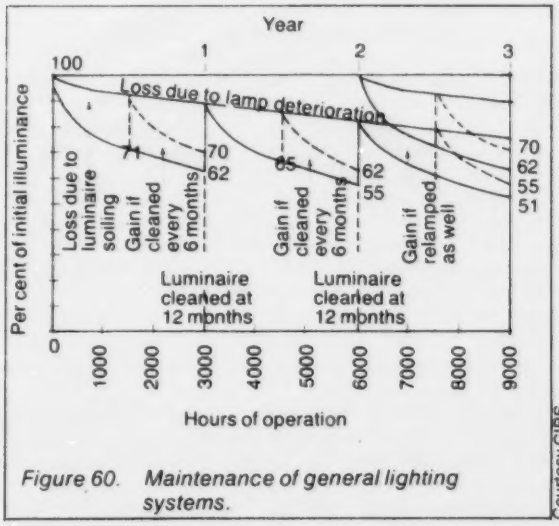


Figure 60. Maintenance of general lighting systems.

h) Reduce wattage for tungsten fixtures.
i) Replace existing fluorescent tubes with reduced-wattage "energy-saving" lamps.
j) Replace existing fittings (such as tungsten fittings in garages) with more efficient types.
k) Redecorate rooms that have dark surfaces and floor coverings. Use light colours to increase reflection.
l) Replace standard incandescent and reflector bulbs in "pot-light" fixtures (see Figure 61) with "ER" bulbs, or use incandescent bulbs with reflectors to increase light output.

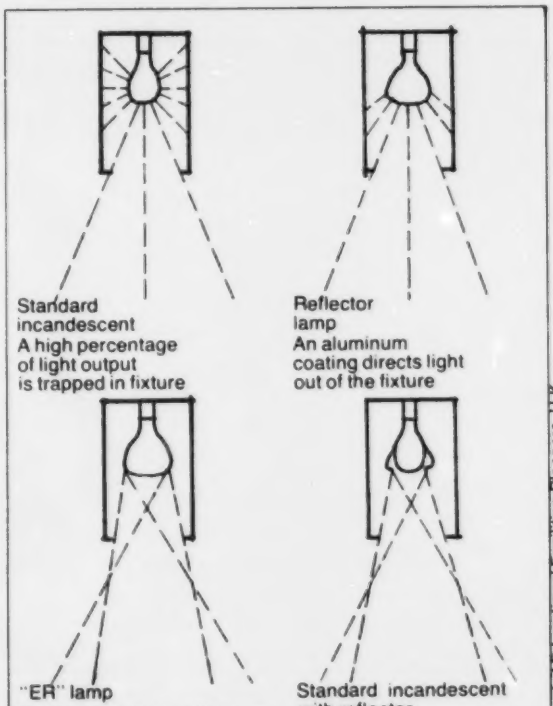

Standard incandescent
A high percentage of light output is trapped in fixture
Reflector lamp
An aluminum coating directs light out of the fixture
"ER" lamp
The beam is focused 55 mm ahead of the lamp, so that very little light is trapped in the fixture
Standard incandescent with reflector

Figure 61. Improving the efficiency of "pot-light" fixtures.

Courtesy Council of Educational Facilities Planners, U.K.

Reduction of Use

Unless the operation of lights can be automated throughout an apartment building, the achievement of a significant reduction in use will depend upon the cooperation of occupants (both tenants and staff). It is therefore in the interests of the owner and operator to encourage users of the building to restrict their use of lights to actual need.

Some automatic devices also may be installed, such as:

- time clocks set to lower lighting levels in public areas during the night
- photo-electric cells that will control outside lighting
- interior photo-electric cells that will switch off electric lights in public spaces when daylighting is adequate
- timer switches on local circuits in areas that are used intermittently (such as equipment rooms, storage rooms, exercise and community rooms)
- movement-sensitive switches that will turn out lights when areas are not occupied.

Electric Motors

Many electric motors currently in use are oversized in relation to the output required of them. As a result, they operate at reduced efficiency and produce a poor power factor. In most instances, it is not cost effective to replace existing oversized motors unless they are nearing the end of their useful life. Professional advice should be sought to determine whether replacement is necessary. If it is, the new motor should be closely matched to the load.

Power-factor Correction

If poor power factor is penalizing operations, it may be worthwhile to install power-factor correction equipment. Low power factor, usually the result of the motor load, can be corrected by the use of capacitors or synchronous motors or by changing motor sizes. Synchronous motors are seldom used outside heavy industrial applications. Power-factor correction devices operate by "counteracting" the effect of the lagging current by connecting a device into the circuit which causes a leading current.

Demand Limiting

The purpose of demand limiting, or "load levelling" as it is sometimes called, is to reduce charges for maximum demand. As it is not uncommon for demand charges to account for up to 50 per cent of the electricity bill, reductions in demand can mean substantial savings.

It is first necessary to find out when maximum demand occurs. In apartments, this is usually during the early evening, when meals are being prepared. For a nominal fee, and on request, the utility company servicing the building may install a temporary recording ammeter, which will record exactly when the peak occurs.

There are two ways in which demand can be limited: load cycling and load delay. In load cycling several pieces of equipment are turned off and on in sequence over the period of maximum demand. For example, in a building with several fans, a fan may be stopped for a specific period, then, before it is restarted, another fan stopped; before this fan is restarted, another is stopped, and so on.

Load delay means that items of equipment such as water heaters, block heaters, snow-melting equipment, and refrigeration compressors are turned off over the high-demand period and turned on again later.

If the maximum demand period is predictable, simple time clocks can be used to reschedule loads. Alternatively, automated load-limiting devices are available which continuously monitor the demand and automatically switch or cycle equipment so as not to exceed the preset level.

Other Measures

All items of electrical equipment should be turned off when not required: for example, refrigerators in vacant apartment units, sauna heaters, swimming-pool filtration equipment, snow-melting equipment, and air conditioners. In buildings with two or more elevators, the number of units in service can be reduced during periods of light traffic. Block-heater "plugs-ins" can be regulated by thermostats so that they do not operate unless the temperature drops below −10 C. Finally, whenever equipment must be replaced — including appliances in individual units — energy-efficient models should be chosen.

CHAPTER 3 MAINTENANCE

Proper operation and maintenance of equipment are at the centre of an energy-efficiency program. In fact, continuous and thorough maintenance is essential to the life and performance of equipment, as well as to control of energy consumption.

The maintenance function includes regular inspection and maintenance, and seasonal maintenance (for start-ups and shut-downs). These are essential to energy-efficient management of an apartment building.

This chapter sets out general procedures that should be included in each of the maintenance functions. It also gives more detailed instructions for the upkeep and repair of major items of equipment. As in the case of operations, these procedures are summarized in the form of a checklist included as an appendix at the end of the handbook (Appendix 4). This information is intended to supplement the instructions contained in a building's operation and maintenance manual.

REGULAR INSPECTION AND MAINTENANCE

There are six basic procedures that should be carried out for all items of mechanical and electrical equipment:

- verification of operation
- lubrication
- check of fluid levels
- check for leaks
- cleaning
- check of wear, misalignment of moving parts, and damage.

Verification of Operation

1. Equipment that is not operated continuously should be inspected while it is not in service to make sure that it will work when it is needed.
2. All components of all systems should be checked from time to time, as their failure or faulty operation may not be immediately apparent.
3. Gauges indicating temperature, pressure, and voltage should be checked while equipment is in operation, as changes from the norm often point to mechanical or other problems. Keeping regular records of performance will help in identifying such changes.
4. Control set-points should be checked to ensure that automatic switches work at the times and temperatures intended.
5. For equipment that is operated sequentially, control devices should be checked. The calibration of controls and gauges should also be verified as accurate.

Lubrication

Bearings

Mechanical equipment includes two types of bearings: ball and roller, and sleeve. Lubricant is essential to the functioning of both types, but there are important differences between them.

In the case of ball and roller bearings, lubricant serves to dissipate heat caused by friction in the bearing, and to protect the bearing from rust, corrosion, and foreign matter. Grease is generally preferred to oil for this type of bearing.

Ball-bearing lubricants tend to thin rapidly with increasing temperature. Equipment that operates at low speed or is not part of a heating system (hot-air or hot-water) may need lubrication only occasionally — though it should always be checked at regular, shorter intervals. But equipment that operates at high temperatures requires frequent inspections and a more viscous (thicker) kind of lubricant.

Sleeve bearings require a lubricant to create a protective film between the bearing and the rotating shaft it surrounds (see Figure 62). In effect, the lubricant should prevent the contact of metal with metal. Oil is preferred for this purpose.

Top-quality lubricants are essential for good upkeep of bearings. Special oils are available for use in extreme (high and low) temperatures.

Manufacturers' recommendations should be followed in applying lubricants. In the event that this information is unavailable, however, follow these basic procedures:

1. Locate all lubrication points, and identify any bearings that are "permanently lubricated"; they will not require further greasing or oiling.
2. Select a suitable lubricant. As mentioned earlier, ball and roller bearings often require grease; if they do, a grease nipple is provided beside the housing (see Figure 63). Sleeve bearings normally require oil and are supplied with an entry hole (often marked "oil" or "oil here") or reservoir, shown in Figure 64. Sometimes the hole is sealed with a bolt to keep dust and air out of the bearing. Recommended grades of oils are listed in Table 9. A heavier grade of oil may, however, be used for old, worn bearings. For greased bearings, a sodium or lithium-based grease, grade 0 or 1, is suggested. The two types must not be mixed.
3. Set up a lubrication schedule, and keep to it. Lubrication every three months is reasonable for most equipment operating in normal environments.

Table 9 Grades of Lubricating Oils

Application	Lubricant
Fractional horsepower electric motors	SAE 10-20
Integral horsepower electric motors, fans, pumps	below 0 C SAE10 0 C to 30 C SAE30 above 30 C SAE30-50

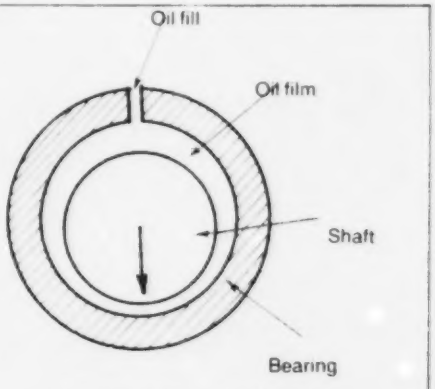


Figure 62. Lubrication in a sleeve bearing.

Where equipment operates at high speeds, or in a hot, humid, wet, or dirty environment, more frequent lubrication is required.

4. Apply lubricant carefully. With grease, avoid the use of high-pressure grease guns. If there is a grease-relief plug (refer to Figure 63), remove it, then pump grease into the bearing until all the old grease is expelled and new grease appears at the seals or plug outlet. If there is no plug, check the application of lubricant by examining the bearing: both sides should be visible. Before replacing the grease-relief plug, allow the equipment to warm up to normal temperature. This will cause the grease to expand and expel any excess. After the plug has been replaced, the bearing housing should be wiped clean.

For oiled bearings, simply fill the tubes or oil caps to overflow and wipe off the excess. In all cases, ensure that the lubrication point is free from dirt, and that the oil or grease is free from contaminants such as dirt and water.

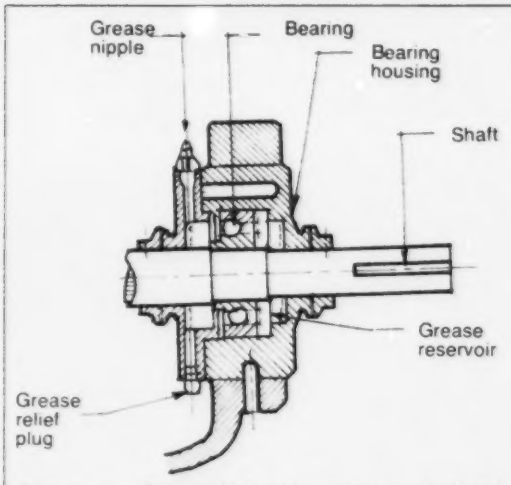


Figure 63. Grease lubrication point in a ball and roller bearing.

Courtesy Peerless Pumps Catalogue

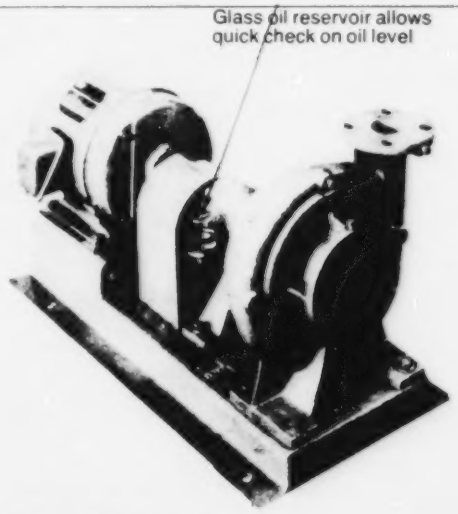


Figure 64. Typical oil reservoir.

Courtesy Peerless Pumps Catalogue

Gear Boxes and Crankcases

Gear boxes (for example, those used on speed-reduction drives for cooling-tower fans) and crank-

cases on air and refrigeration compressors require regular inspection of oil levels and periodic draining and refilling with clean oil. Check manufacturers' recommendations on when to change the oil, and maintain this schedule.

Miscellaneous Items

All moving parts in mechanical equipment can benefit from lubrication, even if they operate very infrequently. In general, all metal-to-metal mechanisms should be oiled lightly at regular intervals. Any machined, non-painted metal surfaces, such as shafts, keyways, and threads, should be cleaned with an oiled rag to prevent rusting. Nylon and other non-metal fittings do not need lubrication. Lubricant should be kept away from electrical contacts.

Check of Fluid Levels

All fluids — such as oil in gear boxes, crankcases, and oil reservoirs, chemicals in chemical dosing plants, and battery electrolyte — should be kept up to required levels. Check at appropriate intervals according to the frequency of use of equipment. Fluids in equipment that is operated rarely or seasonally should be checked before the machinery is put into use again.

Check for Leaks

Many structural components and systems should be checked for leaks. If leaks are not detected and repaired, they can lead to considerable damage of the structure and/or equipment, breakdown, and high energy consumption. The main areas to check are discussed below.

The Building Fabric

As described earlier, infiltration of outside air can cause substantial heat loss from a building. Regular inspections should be made of weather stripping, gaskets, caulking, and door closers throughout the building.

Water leakage can also be a problem. The roof area should be inspected periodically, especially "flashings" where roof-mounted equipment perforates the roofing membrane.

Hot-water Systems

Water leaking from hot-water systems causes two problems: it wastes energy, as it increases the quantity of cold water that must be heated; and the cold replacement water can aggravate corrosion within piping, unless the water is chemically treated beforehand.

Air leaking into the system can also lead to corrosion, or create air locks that impede operation of the equipment. (If, for example, a heating coil was to become filled with air, water would not be able to circulate through it.) In pump systems, air in the liquid can shorten the life of the pump.

Regular (preferably weekly) visual inspections should be made to ensure that water is not leaking from the system. Particular attention should be paid to potential weak points in the system, such as equipment connections, expansion joints, pumps, and valves. At least once a year, or if air locks are apparent (identified by cold equipment that should be warm or hot), the system should be vented to expel trapped air. If air in the system is a recurring problem throughout the year, seek engineering advice. In pump systems, air in the liquid is sometimes indicated by a "scratchy" sound when the pump is in operation. Similar inspections and corrective measures apply to chilled-water supply equipment in air-conditioning systems.

Plumbing Systems

Leaking faucets and automatic float valves in cisterns can waste a significant amount of water and, in the case of hot-water systems, a considerable amount of energy. All facilities in public areas and mechanical systems should be checked regularly, and tenants asked to report promptly any leaks in their own unit.

Refrigerant Systems

Moisture and oxygen in liquid refrigerant can seriously interfere with the performance of equipment. Preventive and remedial measures are described later under Mechanical Cooling Equipment.

Compressed-air Systems

Leaks in compressed-air lines, such as those used in pneumatic control systems, will cause the compressor to work more often, thereby reducing its expected life and increasing energy consumption.

Ductwork

Leaks in ducts, air-handling equipment and dampers waste energy. Outside air dampers should be checked to ensure that they are sealed effectively. Leaks in ducts lead to heat loss and increase the operating load for fans. Any cracks in the ductwork or faulty connections should be repaired, and all access doors in ductwork and equipment be fastened.

Other Systems

All systems — including chemical-feed and oil-delivery systems — should be regularly checked for leaks.

Cleaning

Dirt is a common cause of poor performance in mechanical and electrical systems. It can also shorten equipment life. A range of problems can be created by inadequate cleaning:

- dirt on rotating equipment, such as fan wheels, can reduce efficiency, increase energy consumption, and cause unbalance, leading to wear of bearings
- oil and grease on drive belts and sheaves cause them to slip
- oil and grease spillage and garbage in equipment rooms constitute fire hazards
- dirt and water in a bearing assembly severely limit its life
- dirt that blocks ventilation openings in equipment prevents air cooling and causes malfunction or breakdown of the equipment
- dirt, oil and water that accumulate in electrical equipment can cause short circuits
- dirt and scale in and on heat exchangers reduce their heat-transfer capabilities; in boilers and hot-water heaters, fuel consumption may be increased, and heating tubes burn out
- scale in refrigeration systems, particularly on the condenser/cooling-tower circuit, can impair the performance of the equipment
- dirt and scale on nozzles will change their spray or atomizing ability and in time can stop the flow completely; heat transfer may be impeded; and in oil and gas burners, combustion efficiency may be reduced
- dirt and scale in pipes and equipment reduce or prevent the flow of fluid
- dirt on lights and windows cuts down the amount of light they transmit
- ice collection on cooling towers in winter can reduce their effectiveness and cause structural damage
- dirt and grease in extract systems, particularly in kitchen areas, create a fire hazard
- dirt, scale, and rust on equipment make the tasks of inspection and maintenance more difficult to carry out.

The adverse effects of dirt can be minimized by:

- a well-designed system of filters, strainers, dirt traps and drains
- regular and thorough cleaning
- proper water treatment.

All heat exchangers, nozzles, steam traps, pumps, and instrumentation should be protected by a filter, strainer, or dirt trap (see Figure 65). Kitchen extract systems should be protected by grease filters at the extract grill. Inspection of these items should be carried out regularly: every three to six months when the equipment operates under normal conditions; more frequently when it operates in adverse circumstances.

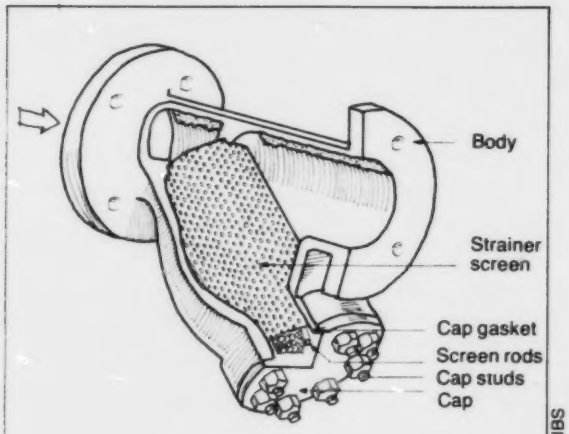


Figure 65. A typical strainer.

Equipment should be kept free of dirt, dust, and contaminants as part of any regular maintenance work from day to day and week to week. All equipment should be thoroughly cleaned once a year. Cleaning should include the draining and flushing of all vessels, such as boilers, hot-water heaters, and cooling-tower pans.

Water treatment is too complex a topic to be dealt with here. A competent water treatment company should be asked to advise on the need for special measures.

Check for Wear, Misalignment, and Damage

All equipment with moving parts eventually shows signs of wear. If these are detected early and remedial action is taken, future malfunctioning and breakdown can be averted. The time and cost of carrying out repairs at this stage are very much less than those involved in repairing or replacing damaged equipment.

Different types of equipment are affected by different forms of wear. Common problems are described below.

Bearings

The main point of wear in rotating equipment is at the bearings. Bearing wear is always accompanied by noise (vibration) and/or heat. Examination of the

equipment while it is in operation will indicate whether either of these conditions exists.

Vibration may be caused by wear in the bearing itself, or by a number of other factors: loose fasteners, misalignment, deterioration of anti-vibration mounts, a bent shaft, or imbalance in the rotating parts. Equipment that is vibrating noticeably should be shut down and investigated, as vibration rapidly accelerates bearing wear.

The first point to check is that all fasteners are tight, particularly mounting fasteners and bolts on sheaves and flexible couplings. The condition of anti-vibration mounts should also be checked to ensure that they are not "short-circuited" by any solid connections. Next check that the driven equipment is properly aligned with the motor drive and that the drive is in good condition.

If these checks prove satisfactory, worn bearings are likely the cause of the problem. On small equipment, it may be possible to pinpoint bearing failure by disconnecting the drive and rotating the motor shaft and the fan/pump shaft manually. The noise created by this action or the "feel" of the rotation should indicate how the bearings are functioning.

In some instances, the source of the noise can be determined by operating the motor with the drive disconnected. If the noise persists, the problem lies in the motor.

The noise may also be traced, with the equipment operating, by making use of a stethoscope or an improvised stethoscope (in the form of a long thin screwdriver, one end of which is placed on the equipment, the other to the ear). The "stethoscope" amplifies the noise produced by the machine and helps in locating its specific source.

A high operating temperature is not always an indication of bearing wear. Bearings on some equipment, especially those running at high speeds, tend to run hot (28°C to 42°C above the space temperature). Accordingly, the normal operating temperature of equipment should be known before the cause of the problem is diagnosed.

On large equipment using pillar housings, the bearings are usually accessible for measuring temperature. A temperature probe or thermometer held against the pillar indicates the bearing temperature. It is advisable to check the operating temperature of equipment at regular intervals, so that any abnormalities can be detected early.

Other Forms of Wear

Any other moving parts, such as fan belts, electrical contacts, brushes in electric motors, diaphragms on control valves, and damper mechanisms should be visually inspected for signs of wear. Even stationary parts of equipment are subject to wear and damage, especially equipment that is installed outside or is subjected to vibration or temperature cycling. Check that bolts and electrical connections are tight, that duct and pipework insulation is not damaged or wet, that electrical insulation has not deteriorated, and that gaskets are in good condition. Where equipment has started to rust or paint is chipped, clean with a wire brush and touch up with paint to prolong its life.

Specific Items of Equipment

Boilers

Ideally, operating data for boilers (such as the flue-gas temperature, operating pressure, and percentage of excess air) should be recorded when the equipment is new and installed to function at maximum efficiency. This information can then be used for comparison with later performance. A second-best alternative for older equipment is to have the boiler serviced to bring it up to its highest possible level of performance, and record the operating data at that time.

Daily, weekly, or monthly checks should be made to identify any deterioration in operating efficiency. Unusual problems and complete servicing of boilers should be handled by specialists (either contractors or manufacturers' service technicians); however, there are a number of jobs that can and should be carried out by the building's maintenance personnel. These are discussed below.

Checking of General Condition

The boiler insulation, refractory (inside lining of the boiler), gaskets, heat-transfer surfaces, and chimney should all be checked.

The insulation and gaskets should be undamaged. Damaged insulation increases heat loss from the boiler; leaking gaskets can upset the air-to-fuel ratio and increase convection losses through the boiler when it is idling (not firing).

Heat-transfer surfaces must be kept clean. Scale or soot on the fireside of these surfaces reduces the efficiency of the unit. Excessive sooting in the boiler stack indicates an incorrect air-to-fuel ratio. The back end of the boiler should be examined regularly; it is most susceptible to deterioration and the formation of scale.

Excessive scaling on the water side also diminishes the unit s efficiency and dependability, and can cause tube damage. Appropriate and adequate water treatment and regular blowdown (bleeding) of steam boilers will keep scale formation down.

The object of blowdown is to maintain a low concentration of dissolved and suspended solids in the boiler. Blowdown may be either manual or automatic. This process should be carried out regularly but no more often than required to maintain an acceptable water quality (see under Blowdown Losses).

The refractory lining should be free of cracks. Note, however, that hairline cracks (up to 3 mm) may be visible when the boiler is cold. These are normal; they close up when the boiler reaches its operating temperature. Larger cracks in the lining should be repaired with an appropriate compound.

Burned or discoloured sections of the boiler casing can indicate deterioration of the lining. Any broken or burned-out sections of lining should be removed from the bottom of the furnace.

Periodically, a check should be made of adjusting screws, locknuts, sheave set screws, and valve packings to ensure that they are all tight. In addition, the boiler should be examined for possible leaks of flue gas.

Routine Cleaning

Any build-up of mineral deposits or corrosion on gas burners should be removed. Fuel filters, ignition electrodes, nozzles, burner-fan blades, the burner-flame stabilizer, the air cone and/or flame-retention head must all be cleaned. Solvents should be used; do not use sharp metal objects to clean components that could be damaged (such as nozzles). At the time ignition electrodes are cleaned, the dimension of the electrode gap should be checked and adjusted if necessary. Wiping carbon deposits off the electrode insulators will reduce the risk of short circuits.

The fire side of heat-transfer surfaces should be cleaned annually, usually by a specialized maintenance crew. Excessive soot and scale should be removed by regular maintenance personnel as required at other times through the heating season.

Water and steam boilers should be drained once or twice a year to remove accumulated sediment. A periodic water analysis can indicate possible deteriorating conditions in the water circuit. Any adverse results should be followed up by a visual inspection of the water side.

Operating Checks

Manufacturers' recommendations for regular operating checks should be followed, especially for safety devices related to water level, temperature, and pressure.

Periodically, the boiler relief valve should be opened to make sure it is operative. The safe operating pressure should not be exceeded before the valve releases. If it is, the valve must be replaced. Intermittent or continuous blowing of the relief valve should be investigated.

Boiler temperature and pressure should be regularly and frequently recorded, so that any malfunction or deterioration of the system can be detected. The flame can also be an indicator of operating problems; many units provide a means of observing the flame during firing.

On natural-draft gas burners, the start of ignition should be smooth, and all jets should have similar flame heights and colour. Any inconsistency indicates clogged jets.

On powered gas and oil burners, the burner flame should not appear "stringy" or "lazy". A poor flame suggests a partially clogged nozzle.

When the boiler shuts down, the flame should go out at the same time. If it does not, the fuel solenoid valve may be sticking.

Boiler Efficiency Test

A boiler efficiency test should be carried out once a year to identify any decline in performance. The test requires special equipment and it is usually more economical to have it carried out by an outside contractor than to assign the job to regular maintenance personnel.

Fans

Lubrication

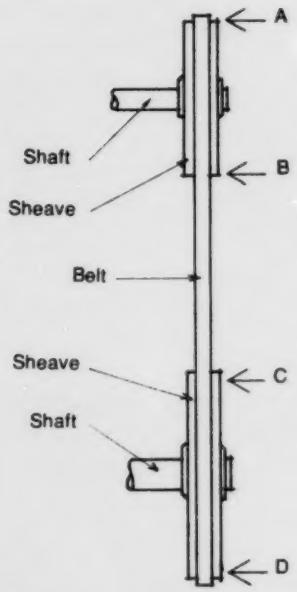
Lubrication of fan and motor bearings should be periodically checked, usually at three-month intervals. Manufacturers' recommendations for lubricant(s) and application should be followed.

Inspection of Couplings

Large fans, particularly centrifugal fans found in air-conditioning and ventilation units, are usually "indirectly driven" by a fan belt connecting pulleys (sheaves) on the motor and fan shafts. The two pulleys must be aligned, otherwise the belt will wear out more quickly than it should. The procedure for checking alignment is illustrated in Figure 66.

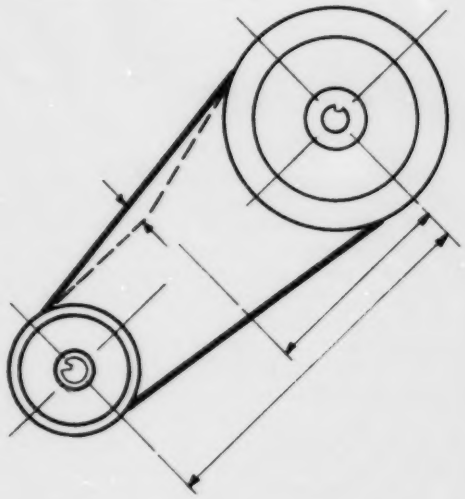
Correct belt tension is also important (see Figure 67). Slippage will occur if the belt is too slack, and the resulting friction will quickly burn the belt. If the belt is too tight, it can create excess pressure on the bearings, accelerating wear and possibly overloading the motor.

At least every three months, fan belts should be checked for signs of wear, such as ruptures in the fabric cover, cracks in the base, bubbling of the cover, burn



Correct alignment is obtained when points A, B, C and D all lie in a straight line. Check by placing a straight edge or stretching a string between the two sheaves. Note: If the pulleys are of uneven width — align the pulley by leaving the same gap between points A and B or between C and D.

Figure 66. Alignment of equipment and motor sheaves.



$$d = \frac{\text{length (L)} \times \text{belt thickness}}{1200\ \text{mm}}$$

e.g. L = 1000 mm, belt thickness = 25 mm

$$d = \frac{1000 \times 25}{1200} = 20\ \text{mm}$$

Figure 67. Correct belt tension.

marks, and ply separation. Shiny belt sides are a sign of normal wear. If wear is evident, the belt should be changed. In the case of multi-belt drives, all belts must be changed at the same time, otherwise differences in belt tension (an old belt will have stretched) can cause slippage. When belts are changed, tension should first be released. Belts should never be pried off. Tension can usually be released by sliding the motor toward the fan (as shown earlier in Figure 40).

The condition of the sheaves should also be checked. The inside faces in contact with the belt should be shiny and free of dirt and rust, and the bottom of the sheave should be dull. If the bottom is shiny, it is likely that the wrong kind of fan belt has been installed.

Check for Vibration

Fans should not be operated if there is any detectable vibration, as the condition will gradually get worse and result in fan or motor damage. Fans should be checked monthly or more frequently for vibration. The following checks should be made if vibration is apparent:

1. Check alignment, as described above.
2. Check tightness of all foundation bolts and bolts holding fan wheels and sheaves to shaft.
3. Check condition of anti-vibration mounts.
4. Check condition of bearings.
5. Be sure the fan wheel is free of dirt. Annual cleaning of the fan wheel is recommended, preferably with a steam or water jet (if this method is used, all bearings must be covered).
6. Check to see if the fan shaft is bent.
7. If all these checks do not reveal the source of the problem, the fan wheel itself may be unbalanced. This normally happens only if the fan has been damaged in some way.

Pumps

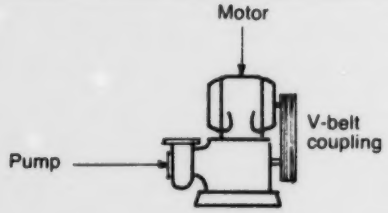
Most pumps used in apartment building systems are the centrifugal type. Maintenance procedures for these pumps are outlined below, together with the procedures for reciprocating pumps.

Lubrication

Lubrication of pump and motor bearings is usually required every three months. Manufacturers' recommendations should be followed. Some manufacturers recommend that sleeve bearings should not be lubricated when the pump is running, because of possible loss of lubrication and premature bearing failure caused by "oil siphoning".

Inspection of Couplings

Pumps equipped with indirect drive use a fan belt and pulleys to connect the fan and motor shafts (see Figure 68). The condition of the fan belt(s) should be checked at least every three months, and worn belts should be replaced. Alignment should be checked annually.



Courtesy CIBS

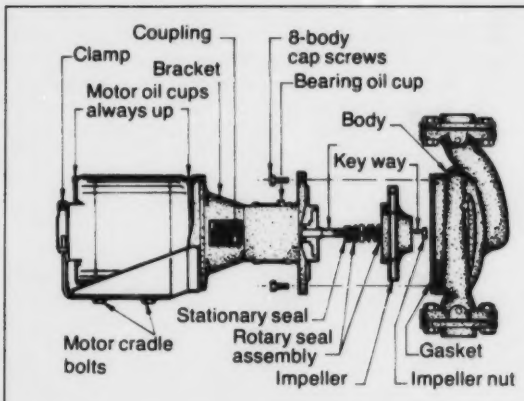
Figure 68. Indirect drive pump.

Direct-drive pumps may be one of three types, as shown in Figures 69, 70 and 71. Those shown in Figures 69 and 70 rely on a flexible coupling between the motor and the pump to transmit power, while providing shock and vibration absorption and allowance for thermal expansion.

With a flexible coupling of the type shown in Figure 70, repairs and constant vibration can cause misalignment. Procedures for checking and adjusting alignment are illustrated in Figures 72 and 73.

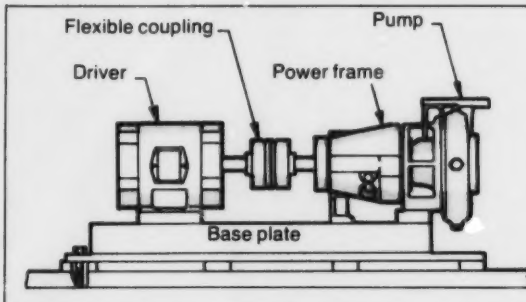
In the case of the close-coupled unit, as long as the pump and motor section are securely bolted together, the alignment should remain true. Constant vibration and the weight of the motor can, however, loosen the mounting bolts. All bolts should therefore be checked at regular intervals to make sure that they are tight.

The "in-line" pump, shown in Figure 71, connects the



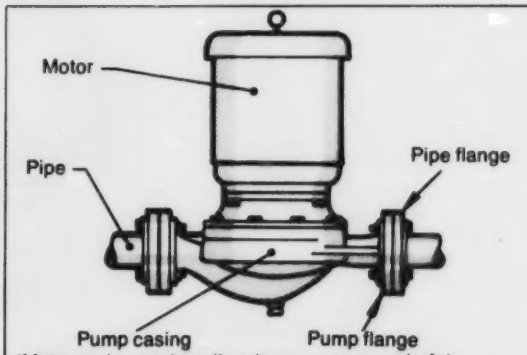
Courtesy Thrush Products Inc.

Figure 69. Exploded view of close-coupled pump.



Courtesy Thrush Products Inc.

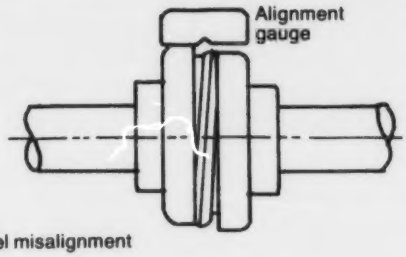
Figure 70. Frame-mounted pump.



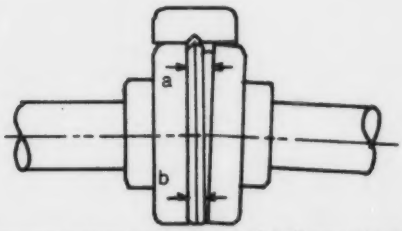
(Motor and pump impeller share a common shaft.)

Courtesy Thrush Products Inc.

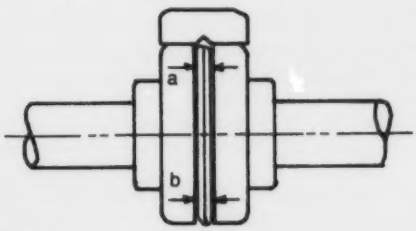
Figure 71. Direct coupled "inline" pump.



Parallel misalignment



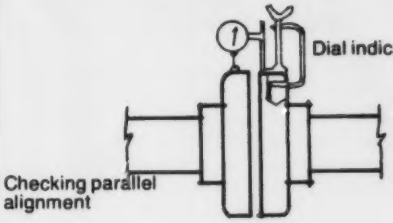
Use alignment gauges to check parallel alignment and "inside caliper gauge" to check angular alignment such that dimension a = dimension b.

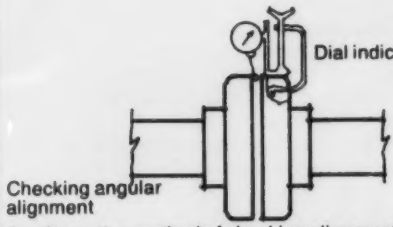


Alignment

Figure 72. Checking alignment with alignment gauge and caliper.

Courtesy Thrush Products Inc.





An alternative method of checking alignment uses a dial indicator with rubber coupling removed. Note position of dial probe for checking angular and parallel alignment. In both cases adjustment in one direction may affect adjustment in other. Recheck angular and parallel alignment after each adjustment.

Figure 73. Checking alignment with dial indicator.

Courtesy Thrush Products Inc.

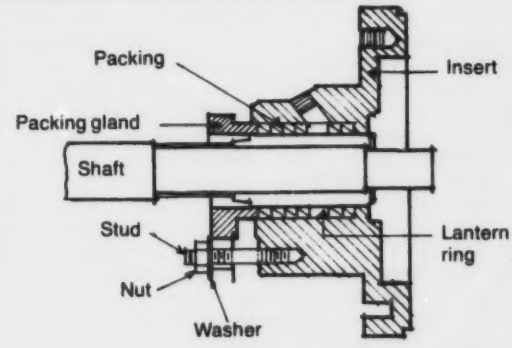


Figure 74. Wet-packed seal.

Courtesy Thrush Products Inc.

motor and pump impeller by a common shaft; thus, they are permanently aligned.

Inspection of Pump Seals

Pump seals are either "wet-packed" or "mechanical". Each type must be treated in a different way.

A typical wet-packed seal is shown in Figure 74. A seal between the pump casing and the impeller shaft is obtained by compressing a packing material around the shaft in a packing box. The correct compression is obtained when a slow drip (at two-to-five-second intervals) is observed from around the packing. This leakage lubricates the packing to prevent it from burning out and to protect the shaft sleeve from wear.

Wet-packed seals are readily identified by this slow drip. Often a funnel and drain are provided under the packing to catch the drips and direct them to the nearest drainage gulley.

Seals should be inspected at least once a month and packing should be adjusted as required. The method is to adjust the packing bolts (there are usually two) by the same amount and never more than one-sixth of a turn per bolt. Packing should be allowed a few minutes to reseal before further adjustment is made.

Mechanical seals almost eliminate leakage and shaft sleeve wear, handle higher temperatures and pressures than wet-packed seals, and require no periodic maintenance. They are, however, more expensive and easily damaged; once a seal starts to leak, it must be replaced. Usually, it is necessary to dismantle the pump when a mechanical seal is replaced (this is not the case for wet-packed seals).

A typical mechanical seal is shown in Figure 75. The bellows prevent leakage between the seal and the pump shaft; the "O" ring seat prevents leakage between the seat and the pump body; and the interface between the washer and seat prevents leakage between rotating and stationary components. The spring is designed to hold the two sealing surfaces together. Lubrication of the two surfaces is provided by the pumped fluid. A very small amount of fluid passes through the seal, although it is so slight that it usually vaporizes and no evidence of it is normally found.

The major causes of seal failure are metal fillings and black iron oxide. Metal fillings may accumulate during installation of the pump system. Iron oxide results from exposure of components to air and water, and it can coat iron and steel parts of the seal assembly. This problem can be greatly reduced by appropriate treatment of the water in the system. Mechanical seals should be regularly inspected for leaks, about every one to three months.

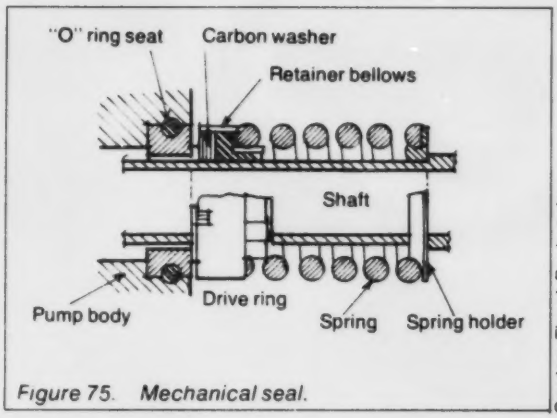


Figure 75. Mechanical seal.

Other Checks

All nuts and bolts should be checked for tightness, and bearings checked for wear. The equipment should be kept clean, ventilation openings in electrical motors kept clear, and oil and grease kept off rubber couplings and rubber anti-vibration mounts.

When carrying out inspection or maintenance of pumps, it is extremely important not to close any valve on the suction side of the pump with the pump running, nor allow the pump to run for more than a few minutes with a closed valve on the discharge; neither should the position of balancing valves be changed.

Centrifugal pumps should never be started or run dry, as this can cause seal failure. If the pump has been dismantled for servicing, it should be primed (filled with liquid and expelled of air) before starting. Manufacturers' recommendations should be followed.

When starting up a standby pump with wet-packed seals, the gland nuts can be slackened off to allow water to wet the seal. The nuts should be tightened after a few minutes of operation.

Procedures for Reciprocating Pumps

Reciprocating pumps are used mainly for pumping boiler feed water. A typical assembly for a reciprocating pump is shown in Figure 76.

The lubrication and coupling inspection procedures described for centrifugal pumps should be followed in

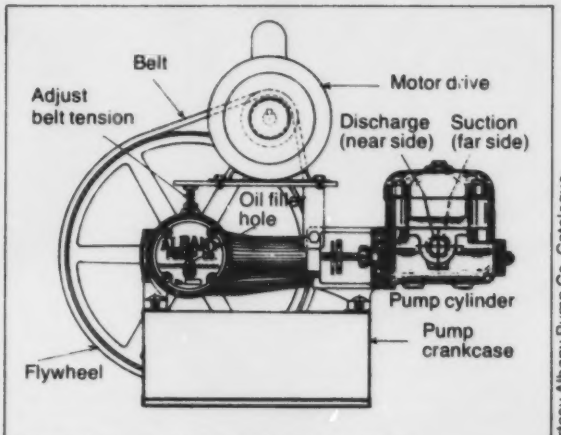


Figure 76. Typical reciprocating pump.

this case as well. Additional maintenance requirements include:

1. Periodic cleaning of pump valves. All dirt and gummy material should be removed from the valves and valve seats.
2. Lubrication of the crankcase. Every six months, the crankcase should be drained and refilled with clean oil.
3. Inspection of plunger cups (pistons) and cylinder liners. This procedure should be carried out annually. Worn or leaking cups reduce the amount of water delivered by the pump.

Steam Traps

The purpose of a steam trap is to hold back steam while passing condensate and air. A malfunctioning steam trap can seriously interfere with the performance of a steam heating system. Air in the system tends to insulate heat-transfer surfaces, thereby reducing the amount of heat transmitted; and condensate in the system can cause damage to piping and space-heating units.

There are several types of steam trap and all should be checked regularly to verify that they are working properly.

Simple Checks

An easy check is to feel the pipe on the downstream side of the trap. If it is excessively hot — that is, as hot as the pipe on the upstream side — it is probably passing steam. If it is cold, it is not working at all. A correctly operating trap should feel moderately hot (as hot as a hot-water pipe).

A second method is to listen to the trap, using a steel rod or screwdriver as a "stethoscope" (hold one end to the pipe and the other to the ear). The difference between the intermittent discharge of some traps and the continuous discharge of others should be distinguishable from the high-velocity sound of a trap blowing steam.

Further Inspections

If the trap is provided with a test valve (a pet cock or small globe valve) and shut-off valve downstream (see Figure 77), use these procedures:

1. Shut off downstream valve, and open test valve. The trap is faulty if there is a continuous stream of steam. Do not mistake "flash steam" (condensate that evaporates on exposure to normal atmospheric conditions) for a steam leak. Leaking steam will blow out continuously and have a bluish cast; flash steam appears whitish and will drift out.
2. Condensate should be observed to flow from the valve: intermittently for inverted bucket or disc type traps; continuously for float traps; and either continuously or intermittently for thermostatic traps, depending upon the load.
3. If any of the above checks shows faulty operation, the trap should be taken apart and inspected for signs of wear, damage, or blockage by dirt. In the first two cases, the trap should be replaced; in the third, cleaning should solve the problem.

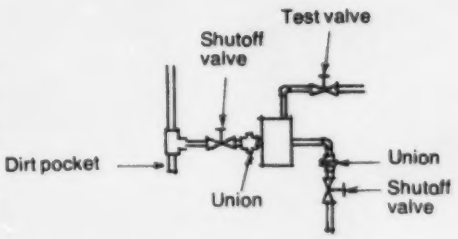


Figure 77. Location of test valve in typical inverted bucket hookup.

Courtesy Heating Plumbing and Air Conditioning Magazine, U.S. (HPAC)

Valves

There are many types of valve, each designed for a particular purpose. Table 10 shows various valve assemblies, with an accompanying description in each case.

Hand Valves

Leakage may occur between the valve packing and the valve stem. Leaks around the stem can cause corrosion; a loose stem may vibrate, causing disc or seat damage. At the first sign of leakage, the packing nut should be tightened.

Valves should be opened and closed periodically, to ensure that they remain operable. Gate valves, such as the one illustrated in Table 10 and Figure 78, are intended to be used only in the fully open or closed positions. They should not be operated when fluid is flowing, as this can damage the valve in time. After a valve has been opened, the handwheel should be backed off one-quarter turn to prevent the valve jamming in the open position.

Exposed valve stems and threads should be kept clean and lubricated for ease of operation and to prevent accelerated wear from dirt and rust.

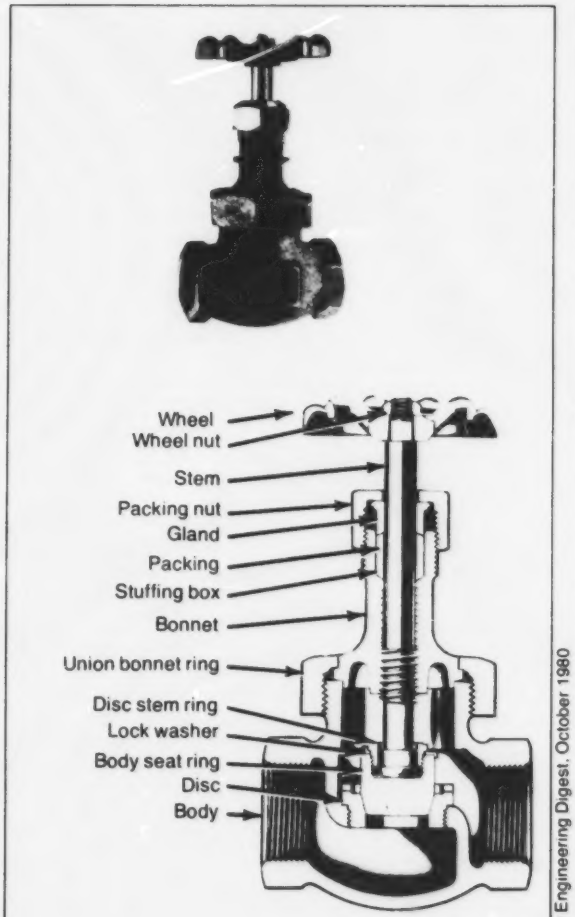


Figure 78. Gate valve (wedge type).

Courtesy Engineering Digest, October 1980

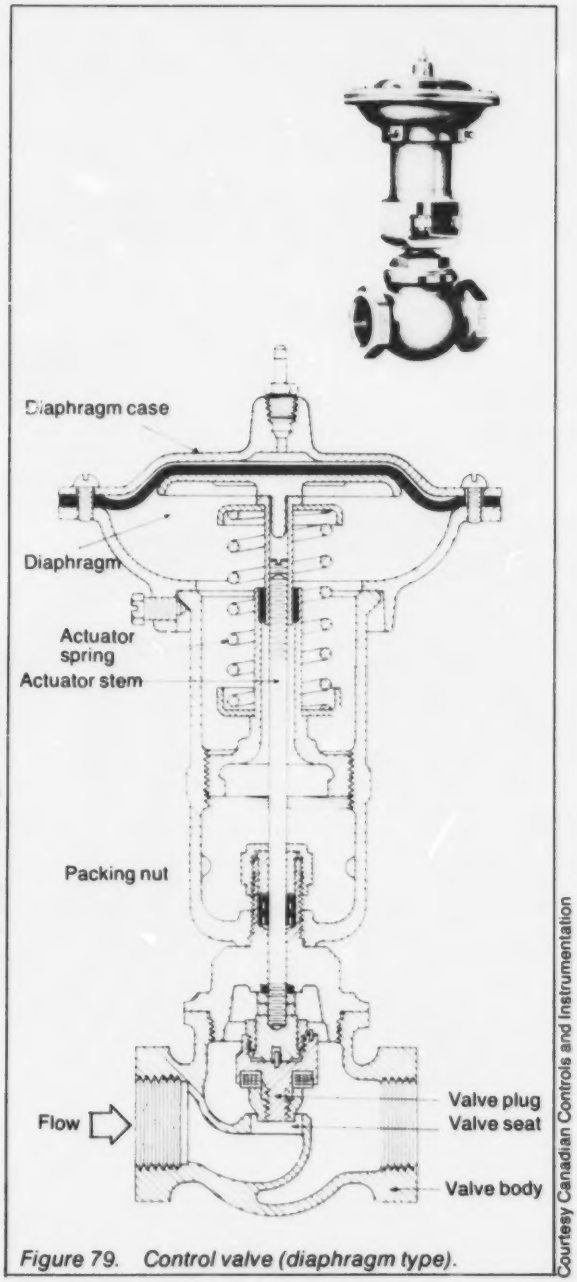


Figure 79. Control valve (diaphragm type).

Courtesy Canadian Controls and Instrumentation

Control Valves

A typical control valve is shown in Figure 79. As with hand-valves, the packing nut should be adjusted to prevent leakage; however, overtightening the nut can cause erratic stem motion and score the valve plug Adjustment of the packing is more critical; it is also required more often for a control valve than for a hand valve, because the control valve is constantly opening and closing.

About once a year, control valves should be opened up and visually inspected. Most control valves can be opened up without removal from the pipework, although a new set of gaskets should be on hand for possible use when putting the valve back together. The trouble-shooting chart (see Table 11) will help in identifying and remedying common problems.

The control sequence should be checked once or twice a year to ensure that the valve modulates (opens and closes) correctly and can both open fully and shut tight when required to do so.

Table 10 Types of Valves and Their Uses

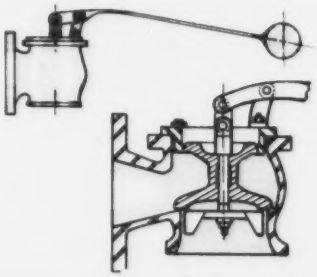
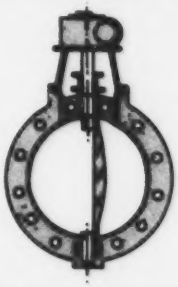
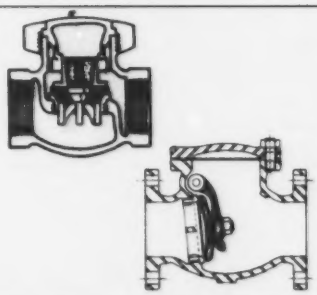
Valve type	Sketch	Description
Ball valves		Used to maintain constant liquid levels in make-up tanks. The ball follows the liquid level in a partially submerged state causing the valve to open up and admit more water with a falling water level and to close with a rising water level. Being in partial equilibrium, the float follows the water level over a wide range of inlet main's pressures, making individual designs unnecessary.
Butterfly valves		Commonly used for many years, and now finding wider use. Their popularity lies in their ease of operation, relatively small size and weight, low head loss, absence of sliding parts and, if correctly sized, good control.
Check valves		Automatic in action, check valves are used in systems where flow in one direction only is imperative. There are two basic types: swing check and lift check. The former is commonly used and has less resistance than the lift check.

Table 10. (cont'd.)

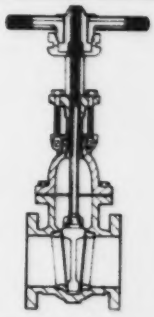
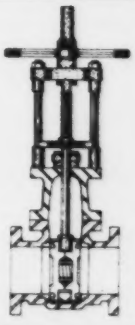
Valve type	Sketch	Description
Cocks		These are the simplest of all closure devices giving on/off and throttling positions. In its simplest form a tapered plug rotates in an enveloping body. Traverse parts in the former covering or uncovering similar counterparts in the latter. Generally used for controlling low pressure water, oil, and almost any liquid that will flow. Not particularly suitable for steam but multi-port flow can be arranged.
Diaphragm valves		The diaphragm isolates the operating mechanism from the fluid being handled and thus they are particularly suitable for the control of abrasive or corrosive fluids.
Gate valves (wedge)		Widely used where uninterrupted flow is required. Not recommended for regulation and should be used fully open or fully shut. The solid wedge with matching tapered body seats has the advantages of strength, long life and not being subject to chatter.
Parallel slide valves		Due to unrestricted bore and very low pressure drop, a design particularly suitable for the control of fluids. Isolation is effected by means of two sliding discs which are traversed across the flow-path of the fluid.

Table 10. (cont'd.)

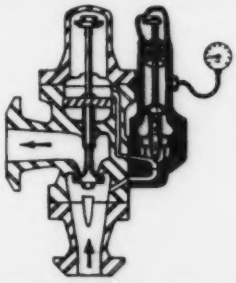
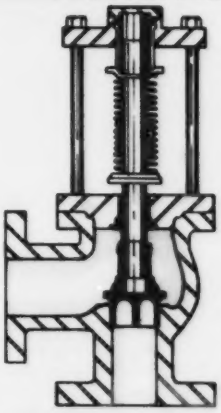
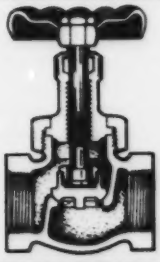
Valve type	Sketch	Description
Plug valves		The plug valve is a refinement of the simple cock suitable for high pressures and temperatures. Pressure drop across the valve is low and seating surfaces are fully protected from line fluid.
Relief valves		A relief valve is an automatic pressure relieving device calculated by the static pressure upstream of the valve and which opens in proportion to the increase in pressure over the opening pressure. It may be spring or direct weight loaded or pilot valve operated. It is used primarily for liquid services.
Safety valves		The regulations in most countries demand that safety valves be installed on all pressure vessels to ensure that maximum design pressure is not exceeded. These regulations vary considerably and thus care should be exercised to ensure that such regulations are known and correctly interpreted. Safety valves are available in several designs of which the following are common examples: (a) An ordinary safety valve is one in which no use is made of the pressure discharged steam to assist the lift of the valve which must be at least 1/24th of the internal diameter of the seating. Used for the protection of low-pressure vessels and pipe systems. (b) A high-lift safety valve is one in which the lift is assisted by the pressure of discharged steam to give a lift of at least 1/12th of the internal diameter of the seating. (c) A full-lift safety valve is one in which lift is assisted by the pressure of discharged steam to give a lift such as will provide an area round the edge of the valve seat to equal the net area through the seat orifice after deducting the area of guides and other obstructions.
Screw-down stop valves		Used to stop or regulate flow of liquid or gas (e.g. steam). Operated by screw and nut mechanism through electric or air motor, manual hand wheel or hydraulic cylinder. May incorporate a globe type body for straight pipe runs or an angled body for converging pipe runs. Principally used as a stop valve and not as a control valve. Source: IHVE Guidebook B, 1970

Table 11 Control Valve Trouble-shooting Chart

Symptom	Possible cause	Remedy
Black or reddish brown carbon type deposits on valve trim (steam systems).	Boiler water-treatment compound carried over into steam system. Excessive deposits can cause sticking.	Remove coating with solvent.
Cuts and nicks in seating surfaces.	Dirt in piping system.	Lap plug into seat using a very light grinding compound. A strainer placed upstream of the valve can prevent dirt entering the valve.
Pit marks in throttle area of valve.	Cavitation.	Alter flow conditions (temperature and pressure) if possible. Choose alternative valve.
Rough and discoloured metal surfaces.	Corrosion.	Use metals more resistant to fluid (change valve) and/or check water treatment.
Deformed or fractured parts (steam systems).	Improperly trapped steam systems allowing "slugs" of condensate to enter the valve.	Check operation of traps and design of steam trapping of system.

Mechanical Cooling Equipment

For many components of cooling systems — for example, heat exchangers, fans, motors, and fan belts — the maintenance instructions outlined earlier apply. Refrigeration compressors, refrigerant circuits, and chillers, however, have special maintenance requirements.

In most instances, especially with large systems and equipment, inspection and servicing should be carried out by a specialist contractor or a manufacturer's service technician, but some checks and minor jobs can be performed by regular maintenance staff.

Every week, the oil level and oil pressure in compressors should be checked. The grade of oil recommended by the equipment manufacturer should be used for topping up.

Every week, the refrigerant "moisture-liquid" indicator should also be checked. The presence of bubbles indicates a shortage of refrigerant. If the colour of the refrigerant indicates "wet", it means there is moisture in the liquid. In both instances, a mechanic should be called to investigate the source of the problem, make necessary repairs, and add refrigerant. Moisture in the refrigerant is particularly critical, as it can cause extensive damage as well as faulty operation.

Equipment should be inspected periodically for unusual operating patterns, such as frequent stopping and starting. Discharge pressure and temperatures, condenser and chilled-water temperatures, and flow rates should all be checked. Log sheets should be kept to record any changes in performance.

Once a year, the condensing-water circuit on water-cooled condensers should be drained, and the tubes and waterbox inspected. (It is recommended that water be drained out in the fall, to reduce the risk of freezing over the winter.) Condenser tubes should be cleaned annually. The water side of the evaporator (chilled-water side) should also be drained down and cleaned, at least once every three years.

The oil filter pressure drop should be checked, and the oil filter and refrigerant dryer changed regularly, in accordance with the manufacturer's recommendations. The oil in the sump should be periodically tested for acidity, using an acid test kit. Oil does not require changing unless it becomes contaminated by water, acid, or metallic particles. Acidity, caused by moisture in the refrigeration system, can damage motor windings, bearings, and other internal parts.

In addition to carrying out the checks described above, regular maintenance personnel should make sure that other inspections are performed by a specialist contractor or service technician. For example, once a year all controls in the system should be calibrated. The refrigeration mechanic should also carry out an annual check on the refrigerant to identify any contaminants. Leak testing of the unit should be carried out at this time.

A vibration test on the compressor motor can indicate developing problems, such as shaft or impeller imbalance or bearing wear. A megohm test on the motor will identify deterioration (reduction of electrical resistance) of the winding insulation. Both these tests require special equipment and should, therefore, be performed by a specialist contractor or service technician.

Cooling Towers and Evaporative Condensers

Figures 80, 81 and 82 illustrate various types of cooling towers and their basic operation. Figure 83 shows a typical evaporative condenser.

In general, the maintenance instructions for system components (fans, motors, valves) should be followed. Special requirements are described below.

Lubrication

Lubrication should be carried out more frequently than suggested for pumps and fans in other systems. Monthly lubrication of fan and motor bearings is recommended, along with a monthly check on gear box lubricant. The gear box should be drained and refilled every three months, or more frequently if the lubricant is found to be contaminated with water. Manufacturers' recommendations for type of lubricant and application should be followed.

Water Treatment

Cooling in the tower is achieved partly through the evaporation of water. As the water evaporates, impurities present in it remain in the unit; and as more water evaporates, the concentration of impurities increases. Any impurities in the air (chemical fumes, salt) can also be absorbed by the water in the tower. To prevent an excessive build-up of impurities, it is recommended that water be bled (run to waste) from the tower at a rate at least equal to the amount of water being evaporated. Unless impurities are removed, scaling or corrosion of the heat-exchange surface can result, which will reduce the efficiency and life of the unit.

If a constant bleed will not control scaling or corrosion, then chemical water treatment is necessary. As mentioned earlier, a detailed discussion of chemical water treatment is beyond the scope of this handbook. Professional advice should be obtained.

Inspection of Water Circuit

The complete water-distribution and reservoir system should be regularly checked. Suction screens should be inspected and cleaned at least once a month; a partially blocked screen will reduce the capacity of the pump. The operation of the make-up float valve should also be checked each month, and cleaned and adjusted as necessary. (The pan-water operating level may range from 50 mm to 150 mm below the centre line of the overflow pipe. Check the manufacturer's recommendations.) The pan should be flushed to remove the build-up of interior growths and solid material, once a

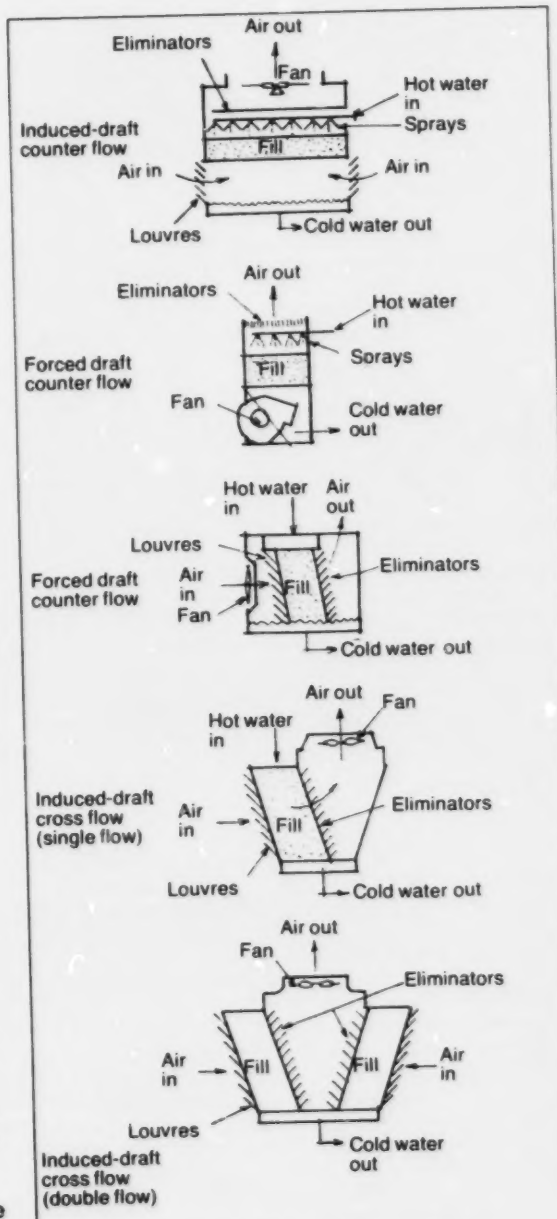
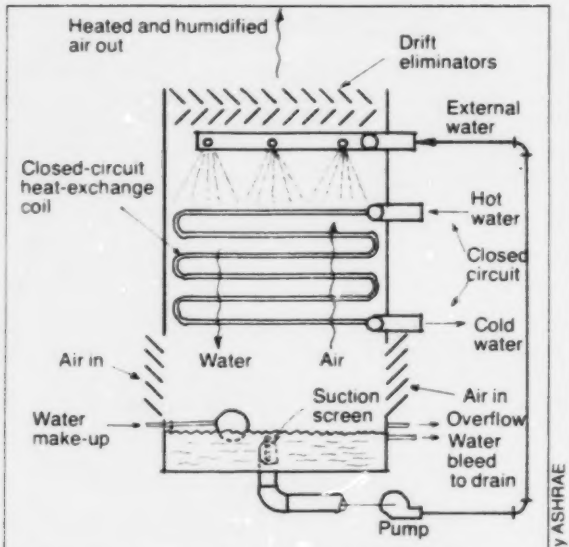


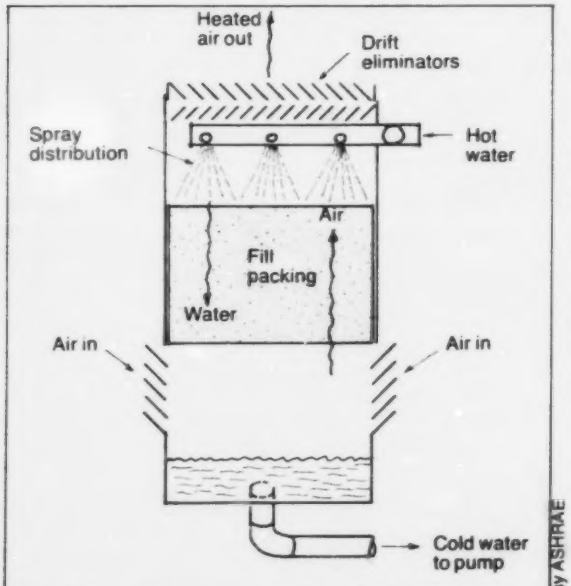
Figure 80. Typical cooling-tower configurations.

Courtesy ASHRAE



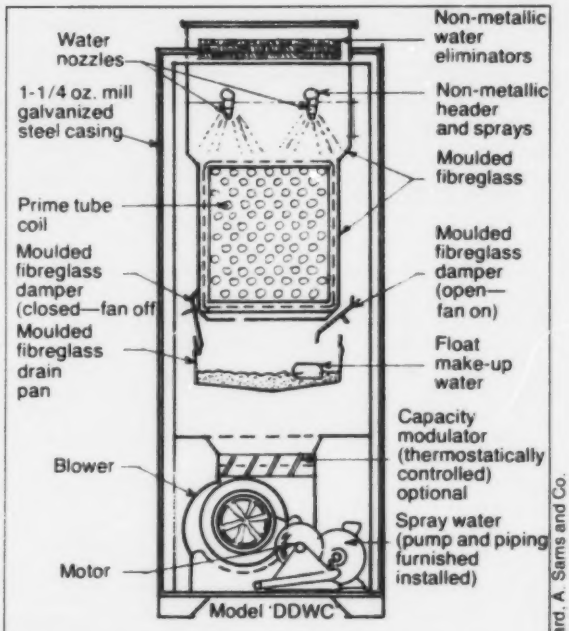
Courtesy ASHRAE

Figure 81. Schematic of indirect-contact cooling tower (fan omitted for clarity).



Courtesy ASHRAE

Figure 82. Direct-contact cooling tower (fan omitted for clarity).



The evaporative cooler differs from a cooling tower in that the fluid being cooled is refrigerant rather than water.

Courtesy P. Howard, A. Sams and Co.

Figure 83. An evaporative cooler.

year or more frequently if the build-up is evident. If this is a continuing problem, water treatment procedures should be improved.

The water-distribution system should be checked every three months to determine whether any debris or dirt has collected. Cleaning can normally be achieved simply by flushing with a hose. Eliminator plates, packing, and structure should be examined for bacterial growth. Biocide dosing should be modified as necessary. Spray nozzles should be inspected monthly and cleaned to prevent clogging.

In apartment buildings, cooling towers are not likely to be operated during the winter months. To prevent frost damage, the cooling tower and any exposed pipework should be completely drained of water.

Electrical Installation

Electrical systems require less routine maintenance than do mechanical systems. (Special instructions for lighting equipment and motors follow this section.)

Installations should be checked for damage and

signs of overheating of cords, cables, and switches. Overheating is indicated by scorching or burning of insulation resulting from either an electrical overload or loose connections. Damaged equipment should be replaced.

Contacts in switchgear and motor-control gear should be checked for severe pitting. Damaged contacts should be replaced.

All electrical equipment should be kept clean, both inside and outside, and all ventilation openings kept unobstructed. Condition of gaskets and possible water leaks in equipment installed outdoors should be checked. Insulators in switchgear should be cleaned.

Switch and contact mechanisms should be lubricated only in accordance with manufacturers' instructions. Contacts should be kept clean of oil. A check should be made for oil leaks from oil-filled equipment, such as transformers and high-voltage switchgear.

Terminal connections on major electrical equipment should be tight. As well as causing overheating — a common cause of equipment failure — loose connections waste energy. The operation of switches and interlocks should be checked.

Lighting Systems

After a few months of operation, dirt on lamps and lighting fittings can absorb as much as one-third of the available light. When this factor is combined with the natural loss of lamp output through age and deterioration of room reflectors, lighting levels may drop to less than half that of the original installation. Proper maintenance can prevent much of this loss, and it may permit a reduction in the number of lamps and fixtures required (as described in Chapter 2).

All lighting fixtures and their components should be cleaned at least twice a year, or preferably every three months. During the cleaning process, the diffuser, lamp, and inside of the fixture should be washed and treated with an anti-static fluid to reduce the attraction of dirt. Diffusers should be allowed to drip-dry instead of being polished; old yellowed diffusers should be replaced. Surfaces within the space being illuminated should be kept clean in order to maintain good reflection capacity.

Lamps can be replaced individually as they burn out, provided that staff are generally available to perform this task. Alternatively, all lamps in a given area can be replaced at the same time, perhaps when fixtures are being cleaned.

Electric Motors

The life of an electric motor is largely determined by the life of the winding insulation, which in turn is dependent upon temperature. Overheating often leads to electrical breakdown, but the cause of the problem is usually mechanical in nature.

A common cause of overheating is inadequate motor cooling, resulting from the accumulation of dirt on or in the motor. Mechanical overload can also cause overheating. Overloading may result from incorrect lubrication of motor or driven equipment, a tight driving belt, misalignment between the motor and driven equipment, accumulation of dirt in the air space between the stationary and rotating parts of the motor, or a worn bearing.

Other common causes of overheating are low voltage at the motor and improper operation of the starter. For example, if a star-delta starter remains in the starting mode (star connected), or if an auto-transformer starter is left in the starting position — both of which reduce the voltage at the motor — overheating will occur.

Overheating of three-phase motors may result from loss of one phase of a supply (the motor will still continue to run unless the motor-control gear protects against loss of a single phase), uneven voltages caused by unbalanced single-phase loads, or faulty contacts at the terminal switch or starter. Excessive vibration, ingress of oil or oil vapour from surrounding bearings, and sustained dampness also cause insulation breakdown and motor failure.

Some problems with motors arise from negligence in the way they are operated. Many, however, can be avoided through attention to maintenance requirements.

Lubrication should be checked every one to three months, depending upon operating conditions, and new lubricant added as necessary. It is important not to overgrease any part of the motor.

Cleaning is essential. Ventilation openings should be kept unobstructed, and the inside of the motor should be cleaned periodically by vacuum or blowing. High-pressure compressed air should not be used, as it can damage winding insulation.

Bearings should be checked for signs of wear, and the condition of driven equipment and motor control gear should be examined. Brushes and brush-gear in DC or single-phase series wound motors (motors with commutators) should also be inspected.

Hold-down bolts should be tight. The shafts of motors that are not in use should be rotated periodically to prevent damage to bearings caused by marks forming on the surface of the bearing races.

Fire-protection Systems

All fire alarm, fire detection, and fire fighting equipment

should be checked regularly and maintained in peak operating condition, so that it will serve its purpose should it be needed.

A daily check should be made at the control panel to ensure that system warning devices, such as power-failure indicators, are not activated. The condition of standby-power batteries should be checked monthly. Terminals should be tight and free from corrosion. If battery terminals are dirty, they should be cleaned and covered with petroleum jelly. The battery electrolyte level and specific gravity should be checked (a hydrometer will be required for testing specific gravity), as well as the battery charging rate, voltage, and test battery supervisor. An alarm should sound if the battery is disconnected.

Where hoses are provided, a check should be made to ensure that hose-reel hand valves can be opened and that the hose itself can be drawn out. Manufacturers' recommendations should be followed for testing and recharging fire extinguishers.

Every month, it is advisable to check at least one manual alarm point to verify operation of visual and audible alarms, and to check the signal at the control panel. A thorough inspection of the entire system should be made once a year to confirm operation of all components, including thermal and smoke detectors, and mechanisms that control or link with ventilation fans and sprinkler flow switches.

SEASONAL MAINTENANCE

All equipment should be thoroughly inspected both when it is shut down and before it is restarted. Repairs should be scheduled for the end of the operating season, so that there will be no delay in starting up equipment when it is next required.

Special precautions are required if there is a danger of water freezing in pipework and equipment. All outside pipework should be drained, or, in some cases, lagged and heated along its length. Stratification of air, or failure of outside dampers or preheat coils, can cause freeze-up of chilled-water cooling coils. The risk of freezing can be prevented only if all the water is drained from the coil. In order to ensure adequate protection, the coil should be first drained, then filled with an anti-freeze solution. The solution should be circulated by a hand pump, or by a local circulating pump, and then drained. The freezing point of the drained anti-freeze/water solution should be checked to make sure it is at the desired level.

PREVENTIVE MAINTENANCE

The purpose of preventive maintenance is to repair or replace equipment before it breaks down. It goes beyond regular maintenance in that it calls for anticipation of problems before they occur and prevention of these problems through early intervention.

Preventive maintenance can produce a number of gains in apartment management:

- improved equipment reliability (that is, reduction of equipment failures)
- improved equipment performance
- increased equipment life and longer periods between major overhauls
- reduced energy consumption
- reduced operating costs (associated with maintenance and energy use)
- better use of capital funds for equipment purchases
- accurate maintenance budgeting.

In addition to improving the building's operating equipment, a further probable benefit is increased tenant satisfaction. Equipment that breaks down or chronically operates below the system's requirements is an inconvenience that tenants (and owners and operators) can well do without.

Preventive maintenance begins with planning. It is necessary to decide what equipment is to be included, what kind of records are to be kept, and when work is to be carried out. Once this groundwork has been laid, inspections can be made and immediate servicing needs identified. Someone must be given responsibility for overseeing the work, making sure that maintenance procedures are carried out, and anticipating future servicing requirements.

This final section describes these various steps in more detail.

Equipment Survey

A complete survey should be made of the building's mechanical and electrical equipment, plumbing fixtures, and architectural hardware. Part of this work may have already been done in preparation for implementing the energy-efficiency program (see Chapter 1). A list should then be drawn up identifying all items that are to be inspected. For these pieces of equipment, the following detailed information should be compiled:

1. Generic description, such as "base-mounted direct drive, centrifugal circulating pump".
2. Specific description, including manufacturer, model, serial number, and rating. For such items as pumps and fans, it is necessary to record these details for both the pump or fan and the motor drive. The information recorded here should be sufficient to enable any parts' supplier to fill an order for replacement parts. All name plate data should be included.

3. Purpose. Describe what purpose the equipment serves — for example, kitchen and bathroom exhaust.
4. Location and access. State where the item is located, how one gains access to it, and how it is identified.
5. Additional information that helps describe the function or operation of the piece of equipment. For example, for an exhaust fan it would be useful to identify the design air flow; how it is controlled ("control by time clock, off 12 midnight, on 6 a.m."); and source of electrical supply ("supplied from panel 'P1' in boiler room, circuit 'RYB3' 3 Phase, 230V supply fused at 25 amp"). Normal pressure, temperature, and other readings should be recorded where gauges are provided.

As discussed in Chapter 1, information about each piece of equipment can be gathered from the operation and maintenance manual kept for the building. All equipment should be examined for verification of recorded data. It is recommended that descriptive detail be recorded in the same units of measurement as those used in original drawings and equipment specifications.

The scope of the inspection list will vary according to the size of the apartment management operation. In small buildings with few staff, it may be feasible to include only major pieces of equipment. In larger operations, many more items may be covered. The general method of carrying out preventive maintenance described here applies equally to all situations.

Inspection and Maintenance Instructions

For every item of equipment or hardware, a master inspection sheet should be prepared. An example is presented in Figure 84.[1] The sheet should record the following information:

1. A full description of the equipment, gathered through the survey described above.
2. A complete description of inspection and maintenance procedures to be carried out for the particular piece of equipment. A note should be made of the frequency of the inspection and any limitation in the scheduling (for example, monthly, every month May to September, once a year in April).
3. Identification of any special tools required for inspection and maintenance.
4. A list of materials and replacement parts required to carry out maintenance requirements.

In some instances, a single inspection sheet may cover several identical or similar items. Steam traps, air vents, and valves, for example, could be handled in this manner.

[1] A blank sample of this form is included in Appendix 2. Copies of this form may be made and used as suggested in the pages that follow.

The reverse side of the inspection sheet should be used for an equipment repair-history. A suitable format is shown in Figure 85. If the past repair history of the piece of equipment is known, it should be recorded here. The form will be used later to record any future repairs.

Maintenance procedures can be developed from this handbook, in combination with recommendations for specific pieces of equipment supplied by manufacturers. If the building is not equipped with operating and maintenance manuals for all items of equipment, these should be obtained from the manufacturer. They are the best guide to the upkeep of the systems that are in place in a particular building.

Work Schedule

When inspection sheets have been developed for all items of equipment, a schedule should be prepared for work to be carried out throughout the year. The first step is to set up sub-master inspection sheets for each inspection to be carried out. For example, if a piece of equipment is to be inspected (or serviced) every three months, four inspection sheets must be provided to cover the work over a year. The sub-master sheets have an identical format to the masters. To save time, photocopies should be made of the completed master sheets, and information that does not apply to a single inspection visit should be deleted (see Figures 86 and 87).

To be able to plan the work schedule, it is necessary to estimate how long inspection and maintenance tasks will take. The times estimated for the example inspection are shown in the bottom left-hand corner of the sheets.

When sub-master inspection sheets have been developed for each inspection and for each piece of equipment, the total work time for the year can be established by adding the estimates noted on all the sheets. The total divided by 52 gives the required inspection time per week. On the basis of this estimate, work can be assigned to the available personnel on a weekly schedule that spans the full year. A weekly journal of the type shown in Figure 88 will assist with this scheduling. Notations should be made in pencil, so that changes can be easily made.

Inspections of a seasonal nature should be assigned first. Priority should also be given to maintenance work on equipment that is known to be operating below par. It may be advantageous, as well, to carry out inspections in one area at one time.

As suggested for master sheets, the reverse side of sub-masters can be used to record the history of completed inspections. A suitable format is shown in Figure 89.

All that remains to complete the planning stage is to organize the sheets in a convenient and accessible reference system. Master sheets may be grouped together in a single binder; sub-masters should be marked with a "week number" and filed together in "weekly" folders.

Inspections

Inspections should be carried out by regular maintenance personnel (or by contractors, if employed staff are not available). Each week the equipment inspector will receive the sub-master sheets for that week and arrange for the work to be carried out.

All the tasks identified on the inspection sheets should be completed methodically: a check mark should be made against each task as it is done. If the work cannot be completed, a brief explanatory note should be added. Where adjustments or minor jobs are carried out in addition to the work shown on the sheet, these should also be recorded.

If additional repair work or inspection by a more qualified person is required, it should be clearly marked on the sheet; the degree of urgency should be indicated. Finally, a note indicating the time taken to carry out the inspection will help in making future estimates of time requirements. Figure 90 gives an example of a completed work sheet.

By the end of each week, all inspection sheets for that period should be returned to the person responsible for supervising the work. Any jobs that have not been completed will have to be rescheduled for another time.

Supervision

The supervisor of preventive maintenance work has several responsibilities. First, he must issue the weekly inspection sheets. The date of issue should be recorded on the reverse side of each sheet (see Figure 91).

When the completed inspection sheet is returned, the date should again be noted, along with the name of the inspector and any comments on unscheduled repairs, time taken, recommendation for major repair, or further inspection requirements (again refer to Figure 91).

If a repair is required, the information should be entered in the equipment-repair history, on the reverse side of the master inspection sheet. A work order should be issued for the work, and the work order number should be recorded. When the work is completed, the date of completion, the name of the person or contractor who carried out the work and the cost of the repair should be noted. The work done should be described concisely and accurately. Details such as cause of failure, warranty-expiry dates, and invoice number may be included. Figure 92 shows how the repair history sheet should be filled out.

The person supervising the work should keep up-to-date records of the progress that is made during the year. The weekly journal referred to earlier can be used for this purpose. Sample entries are shown in Figure 93.

Finally, modifications will likely have to be made in the work schedule from time to time. Inspections and repairs may be delayed for a variety of reasons: staff availability, unexpected emergencies with particular items of equipment, the need to bring in outside help, unrealistic planning of the work load. The inspection sheets can be altered at any time; their chief purpose is to maintain a continuous record of work to be done and work completed.

Uses of Preventive-maintenance Records (PM)

Master and sub-master sheets provide a way of gathering useful information about equipment performance and maintenance costs. This information may be helpful if new purchases are planned, either to replace existing items or to equip new buildings, and it will facilitate future budgeting for the owner or manager of the building. Inspection records can also indicate the work performance of maintenance staff and any contractors brought in to assist with servicing and repairs. If the building is put up for sale, these records can provide evidence of the actual worth of the property and help ease the transition to new ownership for both the purchaser and the building's tenants.

These are just a few of the many possible uses of maintenance records. Owners and managers who adopt the system outlined here will undoubtedly find their own uses for the documentation, over and above the immediate purpose of keeping track of maintenance requirements.

High Rise Apartment, High St., Ottawa **Week No.** **Card No.** 101 1 of 2

Equipment Description: Air conditioner
Type : Company A, model AB, serial number XY7123
Fan : Forward curved, belt-driven centrifugal. Company A, Model B serial number F123.
Motor : 10 HP 600V/30/60 c/s. 1800 rpm Company B. Model M, serial number M123A. Full-load current 8 amps.
Filter : Throwaway type — replacement company C type A.5.
Electrical supply: 30/600V/15 Amp — Panel P1 in electrical distribution room (26th Floor) Circuit RYB-10
Disconnect switch on unit behind access panel.

Location and Access: Apartment roof, north side. Identified as A/H#1 access from elevator equipment penthouse.

Operating Information:

Design air flow 10 700 cfm, fan speed 910 rpm.
Normal operating current 7 amps.
Time clock control (clock adjacent panel P1) on 6 a.m. off 12 midnight.

Inspection and Maintenance:

MONTHLY INSPECTION
(1) Inspect filters and replace if necessary. Note 2 required.
(2) Stop and start fan – check for smooth start and running.
(3) Check for leaks from valves, pipework and connections.

EVERY 3 MONTHS
(1) Carry out above checks.
(2) Lubricate motor — grease type N.D.
(3) Lubricate fan bearings — grease type N.D.
(4) Check belt tension and for signs of wear — replace if worn. (Company B type FB12, 2 required, replace as a pair).

TWICE A YEAR
(1) Carry out above checks.
(2) Check fan and motor mounts, fan bearing and pulley set-screws for tightness.
(3) Check isolation mounts.
(4) Check electrical connections.
(5) Check fan and motor bearing wear.
(6) Check alignment of fan and motor pulleys.
(7) Rotate fan wheel by hand to ensure that it turns freely.

ANNUALLY (Schedule for August or September)

(1) Carry out previous checks.
(2) Inspect heating coil and clean fins.
(3) Inspect unit casing and accessories for paint chipping or corrosion, clean and repair as required.
(4) Clean fan wheel.
(5) Remove any rust from fan and motor shafts and coat with anti-rust.
(6) Check damper operation, blade adjustment, condition of seals. Do not lubricate nylon damper rod bush.
(7) Ensure valves can open and close, lubricate valve stems.
(8) Check condition of all access doors, including hardware and gaskets and ensure that they close properly.

Time for Inspection: Monthly-1/2 hr, 3 month 1 1/2 hr, 6 month-3 hr, 12 month 8 hr **Work done by:** **Date:**

Note: Generic name of equipment to be added immediately after equipment description.

Figure 84. Sample of a master inspection sheet.

Date Reported	Date WO Issued	WO Number	Done By	Cost	Notes

Figure 85. Sample sheet for equipment repair history.

High Rise Apartment, High St., Ottawa | **Week No.** 10 | **Card No.** 101 1 of 2

Equipment Description:

Air conditioner
Type : Company A, model AB, serial number XY7123
Fan : Forward curved, belt-driven centrifugal. Company A, Model B serial number F123.
Motor : 10 HP 600V/30/60 c/s. 1800 rpm Company B. Model M, serial number M123A. Full-load current 8 amps.
Filter : Throwaway type — replacement company C type A.5.
Electrical supply: 30/600V/15 Amp — Panel P1 in electrical distribution room (26th Floor) Circuit RYB-10
Disconnect switch on unit behind access panel.

Location and Access:

Apartment roof, north side. Identified as A/H#1 access from elevator equipment penthouse.

Operating Information:

Design air flow 10 700 cfm, fan speed 910 rpm.
Normal operating current 7 amps.
Time clock control (clock adjacent panel P1) on 6 a.m. off 12 midnight.

Inspection and Maintenance:

MONTHLY INSPECTION
(1) Inspect filters and replace if necessary. Note 2 required.
(2) Stop and start fan – check for smooth start and running.
(3) Check for leaks from valves, pipework and connections.

EVERY 3 MONTHS
(1) Carry out above checks.
(2) Lubricate motor — grease NLGI S.D.
(3) Lubricate fan bearings — grease type M.D.
(4) Check belt tension and for signs of wear — replace if worn. (Company B type FB12, 3 required, replace as a pair).

EVERY 6 YEAR
(1) Carry out above checks.
(2) Check fan and motor alignment, fan bearing and pulley set-screws for tightness.
(3) Check impeller sealing.
(4) Check electrical connections.
(5) Check fan and motor bearing wear.
(6) Check alignment of fan and motor pulleys.
(7) Rotate fan wheel by hand to ensure that it turns freely.

ANNUALLY (Schedule for August or September)

(1) Carry out yearly checks.
(2) Inspect housing and fan for dust, dirt.
(3) Inspect unit casing and accessories for paint chipping or corrosion, clean and repair as required.
(4) Clean fan wheel.
(5) Inspect belt from fan and motor shafts and coat with anti-spark.
(6) Check flexible connection, blade alignment, condition of seals, damper and bearings.
(7) Inspect inlet and outlet louvers, screens, intake and relief vents.
(8) Check condition of all access doors, including hinges and gaskets and ensure that they close properly.

Time for Inspection: Monthly-1/2 hr, 3 month 1 1/2 hr, 6 month-3 hr, 12 month 8 hr

Work done by:

Date:

Figure 86. Sub-master inspection sheet for a monthly inspection.

High Rise Apartment, High St., Ottawa | **Week No.** 14 | **Card No.** 101 1 of 2

Equipment Description: Air conditioner

Type : Company A, model AB, serial number XY7123
Fan : Forward curved, belt-driven centrifugal. Company A, Model B serial number F123.
Motor : 10 HP 600V/30/60 c/s. 1800 rpm Company B. Model M, serial number M123A. Full-load current 8 amps.
Filter : Throwaway type — replacement company C type A.5.
Electrical supply: 30/600V/15 Amp — Panel P1 in electrical distribution room (26th Floor) Circuit RYB-10
Disconnect switch on unit behind access panel.

Location and Access:

Apartment roof, north side. Identified as A/H#1 access from elevator equipment penthouse.

Operating Information:

Design air flow 10 700 cfm, fan speed 910 rpm.
Normal operating current 7 amps.
Time clock control (clock adjacent panel P1) on 6 a.m. off 12 midnight.

Inspection and Maintenance:

MONTHLY INSPECTION
(1) Inspect filters and replace if necessary. Note 2 required.
(2) Stop and start fan – check for smooth start and running.
(3) Check for leaks from valves, pipework and connections.

EVERY 3 MONTHS
(1) Carry out above checks.
(2) Lubricate motor — grease type N.D.
(3) Lubricate fan bearings — grease type N.D.
(4) Check belt tension and for signs of wear — replace if worn. (Company B type FB12, 2 required, replace as a pair).

TWICE A YEAR
(1) Carry out all the checks.
(2) Check fan and motor mounts, fan bearing and pulley set screws for tightness.
(3) Check isolation mounts.
(4) Check electrical connections.
(5) Check fan and motor bearing wear.
(6) Check alignment of fan and motor pulleys.
(7) Rotate fan wheel by hand to ensure that it turns freely.

ANNUALLY (Schedule for August or September)

(1) Carry out previous checks.
(2) Inspect heating coil and clean fins.
(3) Inspect unit casing and accessories for paint chipping or corrosion, clean and repair as required.
(4) Clean fan wheel.
(5) Remove any rust from fan and motor shafts and coat with anti-rust.
(6) Check damper operation, blade adjustment, condition of seals. Do not lubricate nylon damper rod bush.
(7) Ensure valves can open and close, lubricate valve stems.
(8) Check condition of all access doors, including hardware and gaskets and ensure that they close properly.

Time for Inspection:	Monthly-1/2 hr, 3 month 1 1/2 hr 6 month-3 hr, 12 month 8 hr	**Work done by:**	**Date:**

Figure 87. Sub-master inspection sheet for a three-monthly inspection.

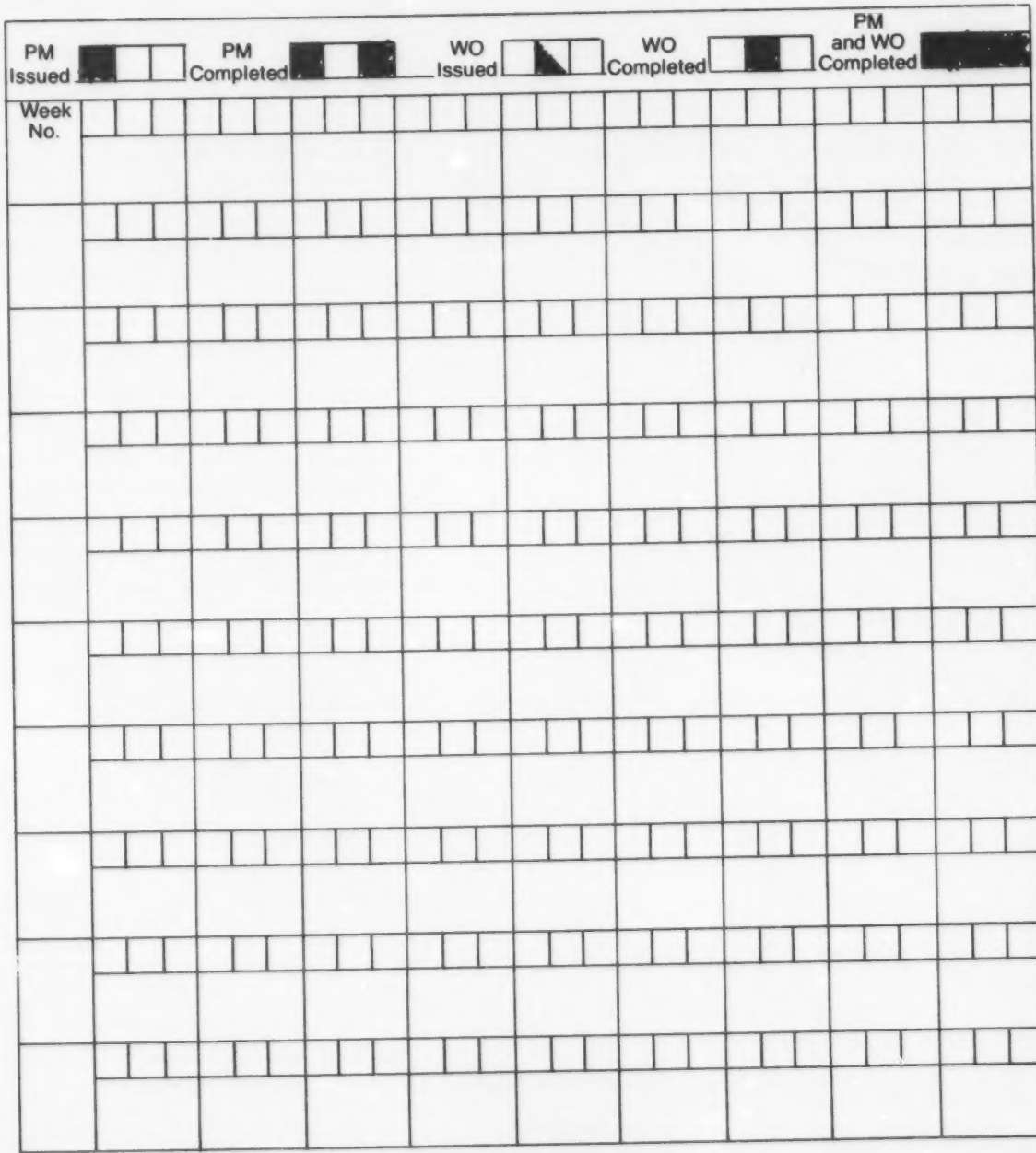


Figure 88. Weekly journal.

Date Issued	Date Completed	Done By	Notes

Figure 89. Inspection history.

High Rise Apartment, High St., Ottawa — Week No. 14 — Card No. 142

Equipment Description: Air conditioner

Type : Company A, model AB, serial number XY7123
Fan : Forward curved, belt-driven centrifugal. Company A, Model B serial number F123.
Motor : 10 HP 600V/30/60 c/s. 1800 rpm Company B. Model M, serial number M123A. Full-load current 8 amps.
Filter : Throwaway type — replacement company C type A.5.
Electrical supply: 30/600V/15 Amp — Panel P1 in electrical distribution room (26th Floor) Circuit RYB-10
Disconnect switch on unit behind access panel.

Location and Access:

Apartment roof, north side. Identified as A/H#1 access from elevator equipment penthouse.

Operating Information:

Design air flow 10 700 cfm, fan speed 910 rpm.
Normal operating current 7 amps.
Time clock control (clock adjacent panel P1) on 6 a.m. off 12 midnight.

Inspection and Maintenance:

MONTHLY INSPECTION
(1) Inspect filters and replace if necessary. Note 2 required. ✔
(2) Stop and start fan – check for smooth start and running. ✔
(3) Check for leaks from valves, pipework and connections. ✔

EVERY 3 MONTHS
(1) Carry out above checks. ✔
(2) Lubricate motor — grease type N.D. ✔
(3) Lubricate fan bearings — grease type N.D. ✔
(4) Check belt tension and for signs of wear — replace if worn. (Company B type FB12, 2 required, replace as a pair). ✔

TWICE A YEAR
(1) Carry out above checks.
(2) Check fan and motor mounts, fan bearing and pulley set-screws for tightness.
(3) Check isolation mounts.
(4) Check electrical connections.
(5) Check fan and motor bearing wear.
(6) Check alignment of fan and motor pulleys.

ANNUALLY (Schedule for August or September)
(1) Carry out previous checks.
(2) Inspect heating coil and clean fins.
(3) Inspect unit casing and accessories for paint chipping or corrosion, clean and repair as required.
(4) Clean fan wheel.
(5) Remove any rust from fan and motor shafts and coat with anti-rust.
(6) Check damper operation, blade adjustment, condition of seals. Do not lubricate nylon damper rod bush.

NOTES: 1 - INSPECTION TOOK 2 HOURS
2 - WATER DRIPPING FROM CONNECTION TO HEATING COIL - CAN'T OVER

Time for Inspection: Monthly-1/2 hr, 3 month 1 1/2 hr, 6 month-3 hr, 12 month 8 hr

Work done by:

Date:

Figure 90. Sub-master sheet with ticks and notes.

PM INSPECTION HISTORY

Date issued	Date completed	Done by	Notes
9 MAR '80	16 MAR '80	J. Brown	LEAK. MOTOR HEATING COIL REPORTED

Figure 91.

EQUIPMENT REPAIR HISTORY

Date reported	Date WO issued	WO number	Done by	Cost	Notes
16 MAR	WO-1 MAR '80	00 1056	A. Contractor	$13.50	FLEXIBLE CONNECTIONS REPLACED

Figure 92.

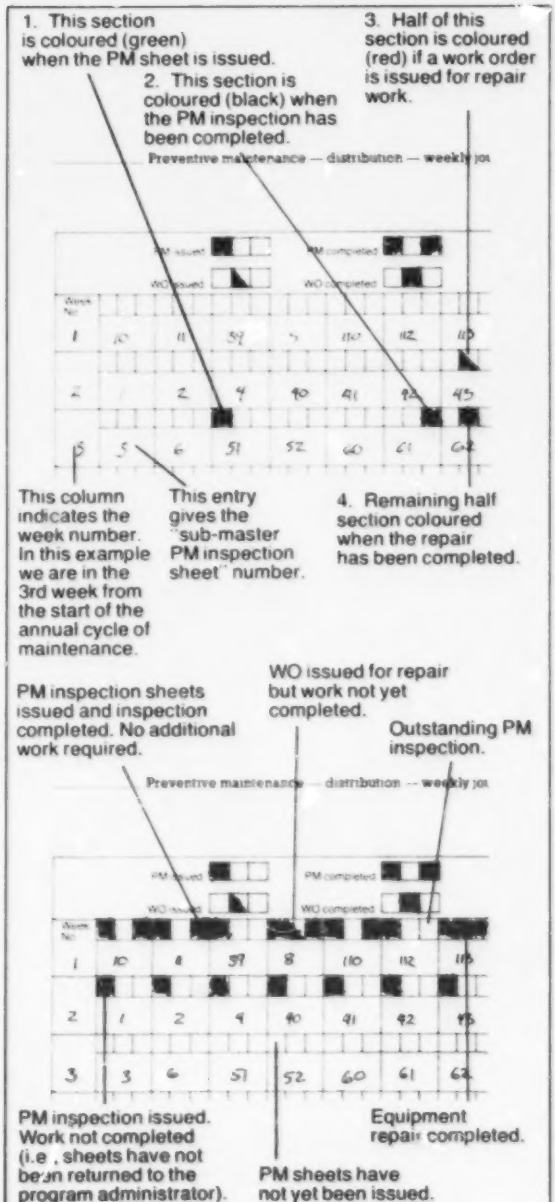

1. This section is coloured (green) when the PM sheet is issued.
2. This section is coloured (black) when the PM inspection has been completed.
3. Half of this section is coloured (red) if a work order is issued for repair work.
Preventive maintenance — distribution — weekly jou
PM issued
PM completed
WO issued
WO completed
Week No.
This column indicates the week number. In this example we are in the 3rd week from the start of the annual cycle of maintenance.
This entry gives the "sub-master PM inspection sheet" number.
4. Remaining half section coloured when the repair has been completed.
PM inspection sheets issued and inspection completed. No additional work required.
WO issued for repair but work not yet completed.
Outstanding PM inspection.
PM inspection issued. Work not completed (i.e., sheets have not been returned to the program administrator).
PM sheets have not yet been issued.
Equipment repair completed.

Figure 93. The use of a distribution weekly journal for administration of the PM program.

APPENDIX 1
CALCULATIONS OF ENERGY USE AND COSTS

THE EXAMPLE

Let us use as an example an air-conditioned apartment building in Montreal, with a total floor area of 22 624 m^2 plus 8 126 m^2 of interior garage area. Number 4 oil is used for both space heating and domestic hot water heating.

Sample oil and electricity bills are shown in Figures 1 and 2. The oil bill is straightforward and needs no explanation. The electricity bill is made up of the following items:

- the first two entries, marked 1 and 2, show the period that this bill covers
- entries 3 and 4 show the present and previous meter readings
- actual consumption in kilowatt-hours is obtained by multiplying the difference between entries 3 and 4 by the multiplier given in entry 5
- thus, consumption = (605 − 502) × 1 150
  = 118 450 kW·h. This is shown as entry 6
- entry 7 shows the maximum demand in the month
- entry 8 shows the tariff or rate code
- entry 9 presents the total amount billed, which is worked out using the tariff M rates shown in Table 1

425 kW demand × $2.55 per kW demand	= $1 083.75
120 hours × 425 kW demand × 3.3¢ per kW·h = 51 000 kW·h × 3.3¢	= 1 683.00
56 000 kW·h × 1.55¢ per kW·h	868.00
Remaining consumption × 0.85¢ per kW·h = (118 450 − 51 000 − 56 000) × 0.85	= $ 97.33
TOTAL	= $3 732.08

A utilities billing record is kept noting all consumption and cost data from month to month and year to year. Figure 3 shows a utilities billing record for almost twenty months. Figure 4 shows a monthly record, also for a twenty-month period. These data provide the basis for the calculations that follow.

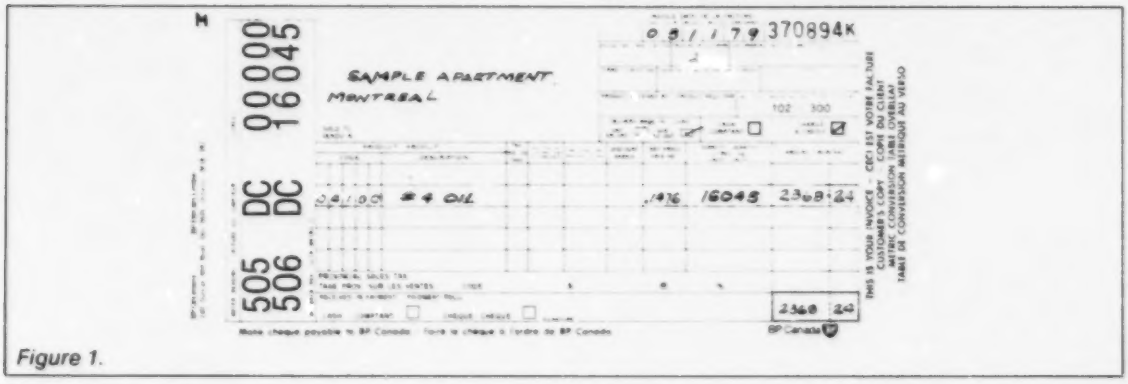


Figure 1.

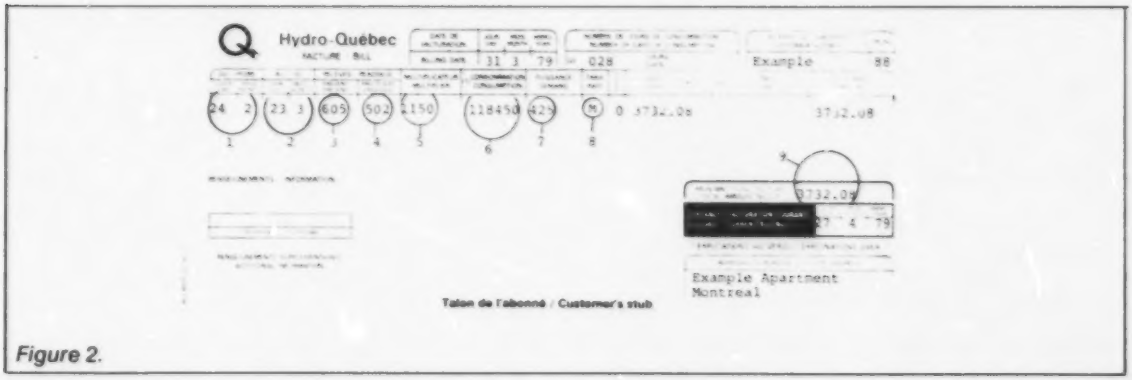


Figure 2.

Table 1

Hydro Quebec Rates

Rate M general use — Medium Power

Rate applies from Jan. 1, 1979 to December 11, 1979

2.55¢ per kilowatt of billing demand, plus
3.3¢ per kilowatt-hour for the first 120 hours of use of billing demand

1.55¢ per kilowatt-hour for the next 56000 kilowatt-hours
0.85¢ per kilowatt-hour for the remaining consumption

Monthly minimum bill — $2.55 per kilowatt of billing demand.

ANNUAL AMOUNTS

Consumption

Calculations are made for a year beginning 1 May and ending 31 April of the following year.

Oil

Part of the delivery made on 5 May 1978 replaces oil consumed in April 1978. It is therefore necessary to apportion 13 727 litres of the 5 May delivery to the two months. This can be done on the basis of the number of days covered in each month: that is, five days in May and fifteen in April (the previous delivery was made on 15 April).

Oil apportioned to May litres $\frac{5}{(15 + 5)} \times 13\,727 = 3\,432$

Annual oil consumption = summation of all other oil deliveries (16 June – 30 April, Figure 3) + 3 432 litres = 329 060 litres.

Oil consumption data must be normalized to take into account varying weather conditions. A degree-day correction factor is applied.

The degree days for the period 1 May 1978 to 30 April 1979 are 4 665, and the average degree days are 4 471; all consumptions will be normalized to this average.

As oil is used in this building for both space heating and water heating, it is desirable to deduct the amount of oil used for water heating before applying the degree-day correction. This can be approximated using the 5 October fuel bill (listed in Figure 3). This bill covers a period from 16 June to 5 October, a period during which there should be little or no need for space heating.

Estimated oil required for hot water = number of litres delivered 5 October.

Number of days from previous delivery = $\frac{26\,545}{111}$ = 239 litres/day (actually 239.144).

Total for year 365 days × 239 litres/day = 87 288 litres/year.

Amount for space heating 329 060 – 87 288 = 241 772 litres.

Applying degree-day correction $\frac{4\,471}{4\,665} \times 241\,772 =$ 231 718 litres

Adding back oil for hot water 87 288.

Total corrected oil consumption 319 006 litres.

Electricity

Consumption of electricity is worked out in the manner described above. In this case, there are two bills that need to be apportioned: those for 23 May 1978 and 25 May 1979.

23 May 1978 bill covers 23 days in May, 6 days in April; therefore, $\frac{23}{(23 + 6)} \times 152\,406 =$

120 874 kW·h in May 1978.

25 May 1979 bill covers 7 days in April, 25 days in May; $\frac{7}{(7 + 25)} \times 134\,118 = 29\,338$ kW·h in April 1979.

Annual electricity consumption = summation of other electric bills (26 June – 23 April, Figure 3) + 120 874 + 29 338 = 1 804 867 kW·h.

Total Kilowatt-hours

In order to estimate total kilowatt-hours of consumption (oil and electricity combined), it is necessary to convert oil data to equivalent kilowatt-hours. Number 4 oil has an equivalent kW·h value of 11. The conversion is calculated as follows:

Corrected oil equivalent kW·h 319 006 × 11 = 1 509 066 kW·h.

Total kW·h, electric + corrected oil, 1 804 867 + 3 509 066 = 5 313 933 kW·h.

From APRIL 29 / 78 to FEB 17 / 79

Building EXAMPLE APT Building Area (excluding garage) 22 624 m²

Address MONTREAL Garage Area 3 126 m²

Date of Meter Reading or Oil Delivery	Fuel 1 Electricity				Fuel 2 = Oil #4		Fuel 3		Water	
	Demand (kW or kVA)	Consumption (kW)	Demand Charge ($)	Consumption Charge ($)	Consumption ( )	Charge ($)	Consumption ( )	Charge ($)	Consumption (m³)	Charge ($)
APR 29 78	460	128 534	1104	2345	-	-			-	-
MAY 3	-	-	-	-	-	-			3236	680
MAY 5	-	-	-	-	13 727	1425			-	-
MAY 23	530	152 407	1272	2694	-	-			-	-
JUNE 6	-	-	-	-	-	-			3234	679
JUNE 16	-	-	-	-	21 636	2246			-	-
JUNE 26	680	198 077	1632	3406	-	-			-	-
JULY 5	-	-	-	-	-	-			3188	670
JULY 25	770	221 829	1848	3805	-	-			-	-
AUG 4	-	-	-	-	-	-			3176	667
AUG 25	710	213 755	1704	3577	-	-			-	-
SEPT 8	-	-	-	-	-	-			3005	631
SEPT 29	600	166 329	1440	2971	-	-			-	-
OCT 5	-	-	-	-	26 595	2756			-	-
OCT 6	-	-	-	-	-	-			2980	626
OCT 23	450	135 584	1080	2371	-	-			-	-
NOV 1	-	-	-	-	18 182	1888			-	-
NOV 5	-	-	-	-	-	-			3026	635
NOV 20	-	-	-	-	23 459	2435			-	-
NOV 25	495	124 440	1068	2276	-	-			-	-
DEC 3	-	-	-	-	-	-			3049	640
DEC 5	-	-	-	-	23 459	2636			-	-
DEC 20	-	-	-	-	29 595	3324			-	-
DEC 25	460	135 100	1109	2378	-	-			-	-
JAN 3 '79	-	-	-	-	25 273	2841			-	-
JAN 4	-	-	-	-	-	-			3026	635
JAN 16	-	-	-	-	23 636	2657			-	-
JAN 26	450	119 122	1148	2727	-	-			-	-
FEB 2	-	-	-	-	30 818	3469			-	-
FEB 9	-	-	-	-	-	-			3060	631
FEB 17	-	-	-	-	26 818	3015			-	-

Figure 3. Utilities billing record.

From FEB 24 / 79 to JAN 10 / 80

Building EXAMPLE APT Building Area (excluding garage) 22 624 m²

Address MONTREAL Garage Area 8 126 m²

Date of Meter Reading or Oil Delivery	Fuel 1 Electricity				Fuel 2 = Oil #4		Fuel 3		Water	
	Demand (kW or kVA)	Consumption (kW)	Demand Charge ($)	Consumption Charge ($)	Consumption ( )	Charge ($)	Consumption ( )	Charge ($)	Consumption (m³)	Charge ($)
FEB 24	490	106 955	1 122	2 561	-	-			-	-
MAR 3	-	-	-	-	-	-			3 119	655
MAR 8	-	-	-	-	29 909	3 362			-	-
MAR 23	425	118 450	1 089	2 698	-	-			-	-
MAR 31	-	-	-	-	27 909	3 137			-	-
APR 5	-	-	-	-	-	-			3 003	631
APR 23	420	116 966	1 071	2 621	-	-			-	-
APR 30	-	-	-	-	18 954	2 075			-	-
MAY 5	-	-	-	-	-	-			3 257	689
MAY 25	500	134 118	1 275	3 002	-	-			-	-
JUNE 3	-	-	-	-	11 454	12 88			-	-
JUNE 4	-	-	-	-	-	-			3 303	699
JUNE 25	620	168 365	1 581	3646	-	-			-	-
JULY 3	-	-	-	-	-	-			2 805	589
JULY 26	655	213 910	1 670	4 132	-	-			-	-
JULY 31	-	-	-	-	11 595	1298			-	-
AUG 5	-	-	-	-	-	-			3 030	636
AUG 24	610	177 950	1 556	3 698	-	-			-	-
SEPT 4	-	-	-	-	-	-			2 241	471
SEPT 25	510	157 187	1 301	3 228	-	-			-	-
SEPT 28	-	-	-	-	12 008	1 772			-	-
OCT 4	-	-	-	-	-	-			2 729	573
OCT 26	390	125 934	995	2 609	-	-			-	-
NOV 3	-	-	-	-	-	-			2 578	541
NOV 5	-	-	-	-	16 045	2 368			-	-
NOV 26	390	103 974	995	2 422	-	-			-	-
DEC 3	-	-	-	-	24 873	3 671			-	-
DEC 5	-	-	-	-	-	-			2 969	623
DEC 22	-	-	-	-	22 887	3 378			-	-
DEC 31	380	133 562	969	2 695	-	-			-	-
JAN 5	-	-	-	-	-	-			2 323	488
JAN 10	-	-	-	-	26 153	3 860			-	-

Figure 3 (cont.) Utilities billing record.

Water

Water consumption is calculated in the same way. The total consumption figure is 36 915 m^3 (assuming that the previous reading was dated 4 April).

Costs

Again, utility costs are calculated by the method used for consumption: the billed amounts are apportioned for those billing periods that lie in more than one fiscal year.

Oil

Total oil costs for the year are $36 192.

Electricity

There are two electricity costs to be calculated: one for consumption, and one for demand.

Consumption is worked out as described above:

23 May 1978 bill (see Figure 3)

$\frac{23}{(23 + 6)} \times \$2\,694.00$ (23 May bill) = $2 136.62 in May 1978

25 May 1979 bill

$\frac{7}{(7 + 25)} \times \$3\,002.00$ (25 May bill) = $656.69 in April 1979

Annual electric consumption cost = summation of other bills (26 June – 23 April, Figure 3) + $2 136.62 + $656.69 = $31 533.31.

It is inappropriate to apportion demand in the above manner, because this charge is based on the maximum demand in any given twenty minutes (or other specified period). There is no way of knowing when in the month this occurred. It is therefore suggested that the annual demand cost be based on the sum of the monthly "as billed" cost, shown in Figure 3.

Annual Demand Cost = $15 573.00
Total Electric Cost = $31 533.31 + $15 573.00
= $47 106.31

Note: It would be much better if line-by-line calculations were provided in every case. This is an example, not an exercise.

Water

The cost of water is calculated by the method used for oil. The total annual is $7 752.34.

Comparison with Annual Energy Targets

Annual targets are indicated in Figure 2, Chapter 1. For Montreal, the targets are:

Apartment 198 kW·h/m^2 yr.
Garage 78 kW·h/m^2 yr.

Target for the building in this example = target × area = (198 × 22 624) + (78 × 8 126) = 5 113 800 equivalent kW·h/yr.

Actual consumption = 5 313 933
= 4% over target.

MONTHLY AMOUNTS

Calculations are made for each complete month; however, they could be made for any other month-long period, such as between the 21st day of each month.

Consumption

Oil

Because oil deliveries are not made on a monthly basis, each delivery must be apportioned to each month as appropriate. Thus, for any given month, delivery records immediately before, during, and after the month must be taken into account. The method is illustrated as follows (using consumption data in Figure 3): 3 January delivery covers three days in January, eleven in December (previous delivery was made 20 December).

Oil apportioned to January = $\frac{3}{(3 + 11)} \times 25\,273 =$ 5 416 litres.

16 January delivery all consumed in January = 23 636 litres.
2 February delivery covers fifteen days in January, two in February.

Oil apportioned to January = $\frac{15}{(15 + 2)} \times 30\,818 =$ 27 192 litres.

Total January consumption = 5 416 + 23 636 + 27 192 = 56 244 litres.

The total is then entered on the "Monthly Utilities Record" form shown in Figure 4.

Electricity

Meters are rarely read on the same date each month; therefore, consumption data should be apportioned in the manner described above. The period should be the

from MAY 1978

Building EXAMPLE APT

Address MONTREAL

Month & Year	Degree Days		Monthly Consumption					
			Fuel 1 Electric		Fuel 2 Oil #4		Fuel 3	
	Average (base)	This Month	kW·h	Corrected kW·h (Electric Heat Only)	(Litres)	Corrected Equivalent kW·h	( )	Corrected Equivalent kW·h
78/05	169	192	167 481		16 826	203 049		
06	38	72	182 067		11 590	127 490		
07	07	27	232 596		7 413	81 593		
08	20	37	205 630		7 413	81 593		
09	106	177	161 111		7 174	78 914		
10	269	338	137 699		18 705	180 389		
11	471	529	116 470		39 765	401 126		
12	765	788	133 318		57 220	613 426		
79/01	865	872	115 228		56 244	614 372		
02	757	730	106 062		47 760	592 069		
03	636	585	131 087		40 497	477 202		
04	369	373	116 119		18 454	201 663		
05	168	232	137 367		10 443	105 666		
06	38	51	170 199		6 385	70 235		
07	07	23	209 670		6 171	67 881		
08	20	34	181 669		6 309	69 399		
09	106	161	143 114		6 543	71 973		
10	269	309	122 392		13 089	136 785		
11	471	439	102 468		29 319	283 591		
12	765	746	118 298		37 940	425 998		

Figure 4. Monthly utilities record

to Dec. 1990

Building Area (excluding garage) 22 624 m²

Garage Area 8 126 m²

		Actual Monthly Costs ($)					Performance Indicators	
Total Fuel	Water	Fuel 1 Electric	Fuel 2 Oil #4	Fuel 3	Water	Total		
Equivalent kW·h	(m³)						Sliding Annual Consumption Equivalent (MW·h)	Cost Avoidance to Date ($)
370 530	2 998	4 079	1747		630	6 456	-	-
309 557	3 209	4 762	1 209		674	6 640	-	-
314 139	3 303	5 824	770		694	7 288	-	-
287 173	2 741	5 199	770		576	6 545	-	-
240 025	3 028	4 308	745		636	5 689	-	-
318 088	3 161	3 512	1 942		663	6 117	-	-
517 596	3 226	3 188	4 262		677	8 127	-	-
796 744	2 975	3 597	6 935		625	10 657	-	-
729 600	3 093	3 806	6 322		629	10 757	-	-
648 131	3 167	3 633	5 369		663	9 665	-	-
608 287	2 895	4 016	4 553		608	9 177	-	-
317 782	3 169	3 673	2 075		666	6 414	-	-
243 033	3 406	4 326	1 174		715	6 215	5280	1 703
240 454	2 955	5 187	718		621	6 526	5 211	2 826
277 551	2 861	5 774	699		601	7 069	5 174	3 880
251 053	2 401	5 322	931		504	6 757	5 138	4 830
215 087	2 664	4 244	966		560	5 770	5 113	5 810
259 177	2 684	3 574	1 932		563	6 069	5 059	7 030
386 059	2 763	3 328	3 690		580	7 498	4 923	9 077
594 196	2 912	3 312	5 599		506	9 417	4 720	12 389

Figure 4. (cont'd.)

same as that used for oil. If meter readings are normally taken around the end or beginning of the month, it is appropriate to use whole calendar months for the monthly summary (this is done here). If, however, readings are usually taken in the middle of the month, it may be more appropriate to use a monthly period defined by the average meter reading date. In this case, oil and water costs must be apportioned to the same period. Again, demand figures are not apportioned.

Water

Consumption is apportioned in the manner described above.

Costs

Monthly costs are calculated by the method used for consumption. With the exception of electricity demand charges, the billed amounts are apportioned to each calendar month.

Total Kilowatt-hours

The method has been described above. For January 1979, estimated daily oil consumption for heating hot water = 239 litres/day (actually 239.144, which is used in the following calculations).

January 1979 consumption = 56 244 litres.
January 1979 heating consumption = 56 244 − (31 × 239.144).

$$= 48\,831 \text{ litres}$$

Correcting for degree days;
degree days this month = 872
degree days average = 865

$$\text{corrected heating} = \frac{865 \times 48\,831}{872}$$

= 48 438 litres

Adding back the oil for hot water:
= 48 438 + (31 × 239.144)
= 55 852 litres

Expressed in equivalent kW·h:
= 55 852 × 11
614 372 equivalent kW·h

Total monthly consumption (electricity and oil):
= 614 372 + 115 228
= 729 600 kW·h

The total should be entered on the "Monthly Utilities Record" as shown in Figure 4.

Sliding Annual Consumption

For May 1979, the sliding annual consumption is the sum of consumption in May (243 033 litres) plus that in the previous eleven months. Sliding annual consumption can be plotted from month to month, as shown in Figure 5. By updating the figure each month, the progress of the energy-efficiency program can be traced.

Cost Avoidance

Cost avoidance is the difference between the "actual fuel cost" and the "predicted fuel cost" had no energy conservation effort been made. Actual fuel costs have been calculated previously and are shown on the Monthly Utilities Record (Figure 4).

To calculate "predicted fuel cost", a base year must be chosen; this is a year that defines energy use before the energy-efficiency program was started. Assuming that the program started May 1979, the base year can be May 1978 to April 1979.

The following examples show the calculation of cost avoidance for oil, electricity, and water for the month of May 1979.

Oil

Actual May 1979 cost = $1 174
May 1978 consumption = 16 826 litres

Adjust for the difference in weather between the two years, using the ratio of degree days.

May 1978 degree days = 142
May 1979 degree days = 232

Subtract oil allowance for hot water of 239.144 litres/day 31 × 239.144 = 7 413 litres.

Heating oil = 16 826 − 7 413 = 9 413
Correcting for degree days, projected 1979 consumption

$$= \frac{232 \times 9\,413}{142}$$

Consumption if no energy program = 15 379 litres
Add back oil for hot water = 22 792 litres
Cost at May 1979 price = 22 792 × 11.24¢/litre = $2 562
Cost avoidance = $2 562 − $1 174 = $1 388

Consumption figures for June, July, August and September should not be adjusted. Assume that oil used in these months is for domestic water heating.

Electricity

Actual May 1979 costs = $4 326 (from Figure 4)
May 1978 consumption = 167 481 kW·h
and demand = 530 kW

At 1979, prices, the demand and consumption costs = $4 726

Cost avoidance = $4 726 − $4 326 = $400

Water

Actual May 1979 cost = $715
May 1978 consumption = 2 998 m³
Cost at 1979 prices = $630

Cost avoidance = $630 − $715 = −$85 (i.e., cost increase)

Total Cost Avoidance

The total for May 1979 = $400 + $1 388 − $85 = $1 703.

The calculation is repeated each month and a running total kept. In this way, it is possible to evaluate the payback on any capital expenditures incurred through the energy-efficiency program.

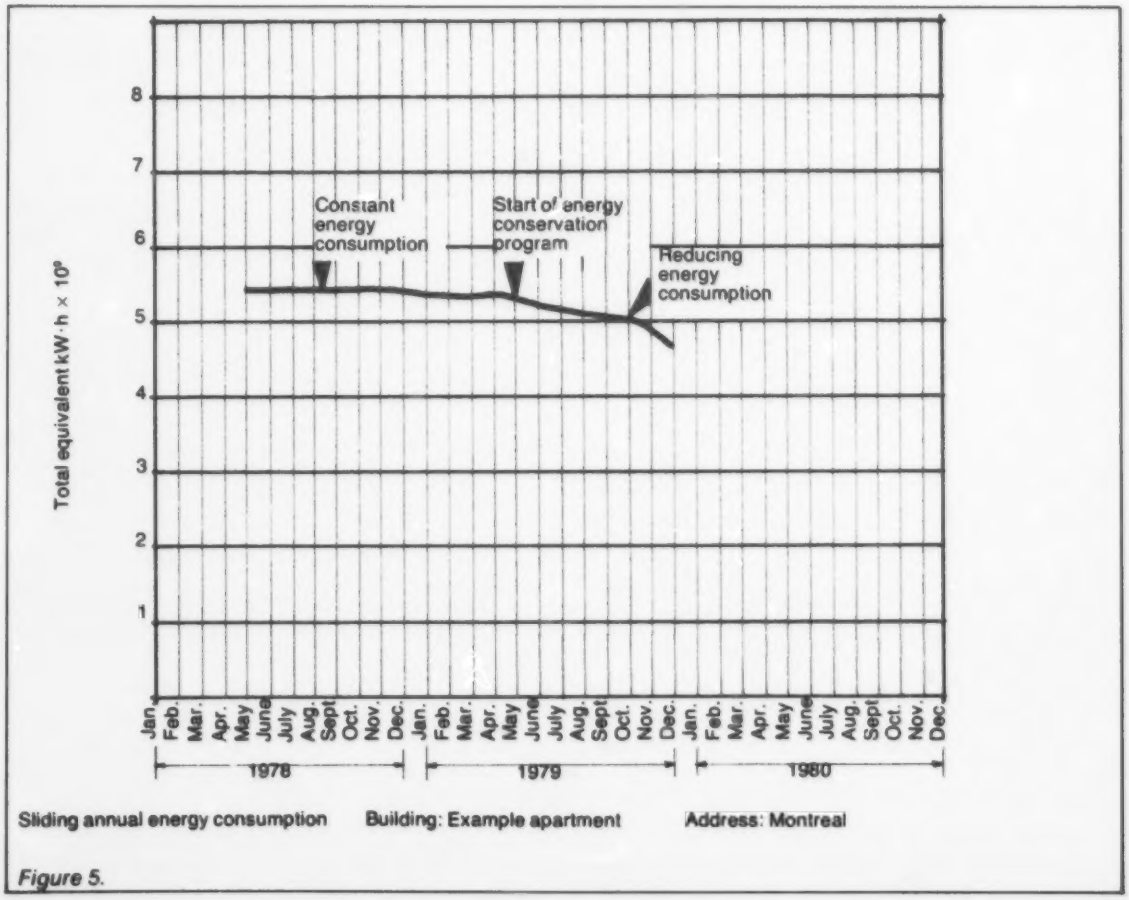


Figure 5.

APPENDIX 2
STANDARD FORMS

MASTER INSPECTION SHEET

Building: **Week No.** **Card No.**

Equipment description:

Location and access:

Operating information:

Inspection and maintenance:

Time for inspection: **Work done by:** **Date:**

EQUIPMENT REPAIR HISTORY

Date reported	Date WO issued	WO number	Done by	Cost	Notes

WEEKLY JOURNAL

PM issued ☐☐☐ PM completed ☐☐☐ PM and WO completed ☐☐☐

WO issued ☐☐☐ WO completed ☐☐☐

Week No.									

P.M. issued: green, P.M. completed: black and green, W.O. issued: red, W.O. completed: red, P.M. and W.O. completed: green, red, black

PM INSPECTION HISTORY

Date issued	Date completed	Done by	Notes

APPENDIX 3
OPERATIONS CHECKLIST

HEATING AND VENTILATION

1. Maintain space temperatures as low as possible, consistent with tenant comfort. Lower temperatures when spaces are unoccupied. See Table 1, Chapter 1, for suggested minimums.
2. Provide ventilation at the minimums suggested in Table 3, Chapter 1.
3. Improve insulation standards of structure if possible.
4. Convert single-glazed windows to double wherever feasible, particularly those windows facing within 80° of North.
5. Ensure that seals on windows are in a good state of repair.
6. Install vestibules in entrances.
7. Seal, at intervals, all vertical shafts passing up the building.
8. Wherever possible, install well-sealed dampers to prevent excessive leakage of outside air into the ventilation system.
9. Shut off extract systems at night, when use of cooking and bathroom facilities is light.
10. Shut off corridor-supply units at night.
11. Shut off ventilation in laundry rooms and exercise rooms when these spaces are not occupied.
12. Control swimming-pool systems with a humidistat.
13. Time-schedule garage exhaust, wherever possible. Alternatively, install carbon-monoxide monitoring equipment.
14. Insulate hot-water pipework, boilers, and heat exchangers.
15. Insulate ductwork and seal any leaks.
16. Reduce air flow and system resistance in warm-air heating systems.
17. Reduce water-flow rate and system resistance in pipework systems.
18. Whenever possible, replace filters with others offering less resistance.
19. Discontinue use of preheat coils if they are not essential to operation of the system and if there is no danger of freeze-up.
20. Remove unnecessary dampers.
21. On heating systems, consider increasing the temperature of supply air to allow a reduction in air volume.
22. Ensure that steam traps are not passing steam.
23. Upgrade space temperature control for hydronic heating systems to provide individual control if possible.
24. In electrically heated buildings, change metering system to individual metering, if the budget will cover the cost of the change.
25. Isolate off-line boilers with valves. If shut-down is temporary, reduce but do not cut off the water flow.
26. At part load, operate multiple-boiler installations sequentially as needed.
27. Install stack dampers on boilers.
28. Bleed steam boilers only as often as required.
29. If domestic water is heated by the boiler, install a second small boiler sized to handle the load during summer.
30. When boilers and burners require replacement, acquire equipment that is more energy efficient.
31. Install heat-recovery devices wherever possible.

COOLING

32. Reduce solar gain through windows.
33. Seal wall and window-mounted air conditioning units.
34. Use an economizer cycle if outside air is used during cooling.
35. Increase chilled-water temperature.
36. For multiple-chiller installations, operate chillers sequentially as needed.
37. Isolate off-line chillers.
38. Replace air-cooled condensers by cooling towers.
39. Avoid simultaneous heating and cooling.
40. Operate cooling equipment only when necessary.
41. Install automatic tube cleaners in condensers.
42. Lower condenser-supply water temperature.

DOMESTIC HOT WATER

43. Turn off dhw circulating pumps at night.
44. Increase efficiency of water heater.
45. Insulate dhw supply pipes and storage tanks.
46. Use heat-recovery techniques.
47. Install solar-heating equipment, if the budget permits.
48. Reduce water-flow rates and temperature.

LIGHTING

49. Maintain illumination at levels suggested in Table 2, Chapter 1.
50. Install efficient light sources and fixtures.
51. Locate fixtures where they will be most effective.
52. Adjust design and decoration of space for maximum lighting effect.
53. Replace yellowed and inefficient lens covers.
54. In fluorescent two-lamp fixtures, wherever possible wire two fixtures from a single ballast or install a shorting or phantom tube.
55. Remove unnecessary fixtures.
56. Replace existing ballast with high-efficiency types.
57. Reduce wattage for tungsten fixtures.

58. Replace existing fluorescent fixtures with low-wattage lamps.
59. Replace standard incandescent and reflector bulbs in "pot-light" fixtures with ER bulbs, or use incandescent bulbs with reflectors.
60. Install time clocks to reduce lighting in public spaces during unoccupied periods.
61. Install photo-electric cells to control outside lighting.
62. Install photo-electric cells to switch off lights in public areas illuminated by daylight.
63. Install timer switches on local circuits in intermittently occupied areas.
64. Install movement-sensitive switches to turn out lights in intermittently occupied areas.

OTHER ELECTRICAL SERVICES

65. Replace oversized motors with equipment closely matched to the load.
66. Choose high-efficiency motors.
67. To correct for poor power factor install capacitors across individual motors or the incoming supply.
68. Cycle use of equipment that does not need to be operated continuously.
69. Temporarily turn off equipment during periods of high demand.
70. If the maximum-demand period is predictable, install time clocks to reschedule loads.
71. Turn off all electrical equipment when not required.
72. Reduce the number of elevators in service during periods of light traffic.
73. Regulate block-heater "plug-ins" in accordance with outdoor air temperature.
74. When equipment and appliances are replaced, choose energy-efficient models.

APPENDIX 4
MAINTENANCE CHECKLIST

GENERAL MAINTENANCE

Leaks

1. Check for leaks in the building fabric: inspect weather stripping, gaskets, caulking, door closers, and roofing, especially "flashings".
2. Check for leaks in hot-water systems: inspect equipment connections, expansion joints, pumps and valves.
3. Regularly inspect plumbing systems in public and service areas, particularly hot-water controls.
4. Check for leaks in chilled-water and condenser-cooling systems, compressed-air systems, ventilation systems (ducts, air-handling equipment and dampers), chemical-feed and oil systems.

Cleaning

5. Check, clean and replace filters to maintain efficiency.
6. Keep all equipment clean, removing dirt, dust, scale, rust, and any contaminants as they accumulate.
7. Schedule a thorough cleaning of all equipment once a year.
8. Have water treated to remove contaminants.

Wear

9. Check for wear in rotating equipment.
10. Inspect all fan belts, electrical contacts, brushes in electrical motors, diaphragms on control valves and damper mechanisms.
11. Check that bolts and electrical connections are tight.
12. Inspect duct and pipework insulation to ensure that it is not damaged or wet.
13. Check for deterioration in electrical insulation.
14. Check gaskets to ensure that they are in good condition.
15. Repaint rusted or damaged equipment.

Heating

16. Check the air-to-fuel ratio to ensure efficient combustion.
17. Check boiler stack temperature.
18. Check flues and chimneys for blockages or improper draft conditions.
19. Annually clean all heat-transfer surfaces.
20. Periodically clean boiler equipment, including gas burners, fuel filters, ignition electrodes, nozzles, burner fan blades, burner-flame stabilizers, and air cone/flame-retention head.
21. Regularly check all gaskets, adjusting screws, locknuts, sheave set screws and valve packings.
22. Check for cracks in the boiler refractory lining and repair as necessary.
23. Inspect the boiler insulation to ensure that it is not damaged.
24. Repair all leaks in water, steam, gas and flue-gas systems.
25. Periodically analyze boiler water.
26. Check burner firing period.
27. Inspect oil-line strainers. Clean or replace if dirty.
28. Make regular operating checks according to manufacturers' recommendations.
29. Open boiler relief valve to ensure that it is functioning.
30. Log boiler temperature.
31. Log boiler pressure.
32. Regularly check all steam traps.

Cooling

33. Each week, check oil level and pressure in compressors.
34. Each week, check the refrigerant moisture — liquid indicator.
35. Look for unusual operating conditions.
36. Regularly check discharge pressure and temperature, condenser and chilled-water temperature and flow rates.
37. Regularly check oil filter and refrigerant dryer and change as required.
38. Periodically test oil in sump for acidity.
39. On evaporative condensers, each month lubricate fan and motor bearings and check gear-box lubricant.
40. Once a year, drain the condensing water circuit on water-cooled condensers and check tubes and waterbox.
41. Annually clean condenser tubes.
42. Annually have all controls recalibrated.
43. Annually test refrigerant for contaminants.
44. Perform vibration test on compressor motor to check for shaft or impeller imbalance or bearing wear.
45. Use megohm tests to check deterioration of compressor-motor winding insulation.
46. Bleed water from cooling towers to remove impurities.
47. Chemically treat water if bleeding cannot control scaling and corrosion.
48. Regularly check water-distribution and reservoir system.

49. Each month, inspect and clean suction screens.
50. Each month, clean, adjust and check operation of float valve.

Fans

51. Every three months, or according to manufacturers' recommendations, check lubrication of fan and motor bearings.
52. Check all belts for alignment, tension and signs of wear.
53. Check fan for signs of vibration.

Pumps

54. Every three months, or as recommended by the manufacturer, lubricate motor and pump bearings.
55. At least every three months, check condition of belts.
56. Check alignment of direct-driven pumps.
57. Inspect wet-packed seals monthly and adjust as required.
58. Every one to three months, inspect mechanical seals for leaks.
59. Check all nuts and bolts for tightness and bearings for wear.
60. For reciprocating pumps, periodically remove all dirt and gummy material from valves and valve seats; every six months, drain and refill the crankcase; and annually inspect pistons and cylinder liners for signs of wear.

Valves

61. Check for leaks and ensure packing is tight.
62. Verify operation of hand valves by opening and closing them periodically.
63. Keep exposed valve stems and threads clean and lubricated.
64. Once a year, visually inspect control valves by opening them up.
65. Verify control sequence of control valves once or twice a year.

Electrical Installations

66. Inspect for damage and overheating of cords, cables and switches.
67. Check contacts in switchgear and motor-control gear for pitting.
68. Check condition of gaskets for equipment installed in damp or dirty environments.
69. Check for water leaks in equipment installed out of doors.
70. Check for oil leaks from oil-filled equipment.
71. Lubricate switch and contact mechanisms according to manufacturers' recommendations.
72. Check operation of switches and interlocks.
73. Check tightness of terminal connections.

Lighting

74. Clean light fixtures at least once a year.

Motors

75. Every one to three months, check lubrication.
76. Inspect brushes and brush gear.
77. Periodically clean inside motor by vacuum or blowing.
78. Check bearings for signs of wear.
79. Check condition of driven equipment and motor-control gear.
80. Check hold-down bolts for tightness.
81. Rotate shafts of motors not in use.

Fire Protection Systems

82. Daily, check control panel.
83. Each month, check standby batteries: terminals, electrolyte level, specific gravity, charging rate, voltage and test battery supervision.
84. Check that fire-hose reel and hand valve can be opened and that hose can be drawn out.
85. Test and if necessary recharge fire extinguisher according to manufacturers' recommendations.
86. Each month, check manual alarm points.
87. Thoroughly check entire system once a year.

About this book

This handbook is for people who make decisions about the way a building is run — owners, operators, property managers, superintendents and maintenance staff — all who are responsible for the day-to-day functioning of a residential building. It tells them how to assess the energy efficiency of a building and how to improve it.

Multi-unit buildings contain engineering systems which provide residents with a comfortable environment. These systems include heating and ventilation, hot water, lighting and cooling. They all consume energy and the amount they use depends on several factors — the size and design of the systems, the quality of the equipment, the way it is operated and the kind of maintenance it receives.

Energy Efficiency in Multi-Unit Residential Buildings sets out the levels of energy efficiency to aim at, and gives practical guidelines for operating the various types of equipment and outlines procedures for maintaining them. Four appendices provide detailed, practical examples of checklists and forms that will help users apply the methods described in the book.